PRACTICAL BREWING.

By E. R. SOUTHBY

A

SYSTEMATIC HANDBOOK

OF

PRACTICAL BREWING:

INCLUDING

A FULL DESCRIPTION OF THE BUILDINGS, PLANT, MATERIALS AND PROCESSES

REQUIRED FOR

BREWING ALL DESCRIPTIONS OF BEER,

BOTH FROM MALT ALONE AND FROM MIXTURES OF MALT WITH

ALL DESCRIPTIONS OF UNMALTED GRAIN.

ALSO THE USE OF SUGARS, AND ALL OTHER MATERIALS, WITH FULL PARTICULARS AS TO

HARDENING BREWING WATERS, ETC.

BY

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SECOND EDITION.

London:

E. R. SOUTHBY, 24, HOLBORN VIADUCT.

1885.

IPSWICH:
PRINTED BY S. H. COWELL, BUTTER MARKET.

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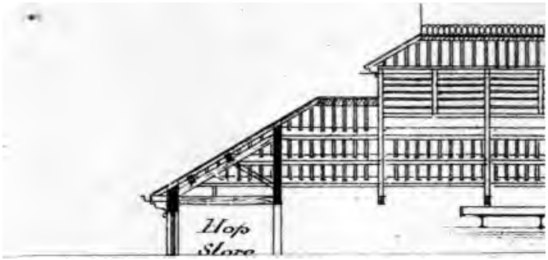
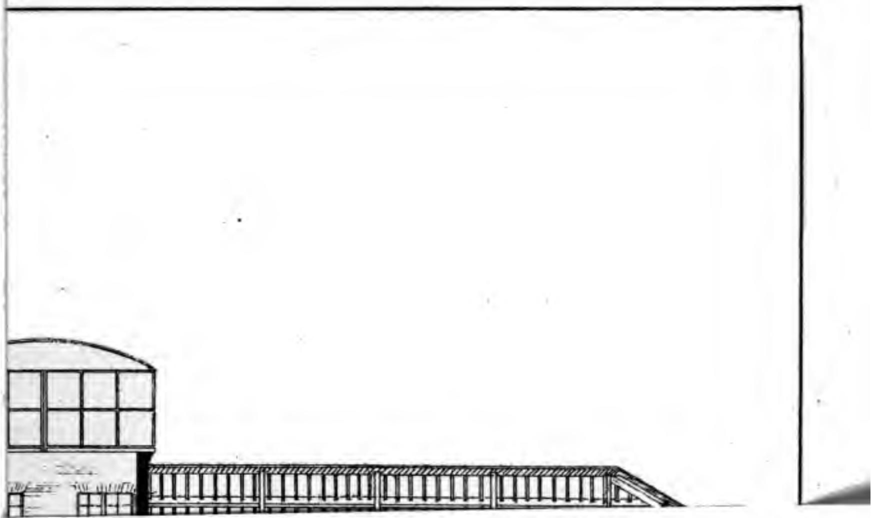




BREWING:

PRACTICALLY & SCIENTIFICALLY CONSIDERED.

INTRODUCTORY.

THE title of most of the earlier works on my subject was not unfrequently comprised in the words "The Art and Mystery of Brewing," or even if those words were not used, the subject was treated in a manner which closely corresponded with them. My present object on the other hand is so far to avoid the conjunction of such terms, that I shall endeavour to show that the very essence of the one is incompatible with the existence of the other. Perfection in brewing, like perfection in any other manufacture, or, indeed, in any series of complex and delicate operations, can only be continuously maintained by a thorough knowledge of the nature and qualities of all the materials employed, and of the different effects produced by the slightest variation of the working processes.

To whatever extent there is any mystery shrouding the properties of the materials, or any uncertainty in obtaining the desired results, from materials, the properties of which are well known, to that extent is the art and practice of brewing dubious, and liable to entail loss.

The mature judgment of intelligent experience has always done good practical work, so long as the conditions upon which that experience was founded were not materially changed by necessity or expediency. But as soon as the best "rule-of-thumb" brewer is compelled to deviate from the beaten path—and this deviation is becoming daily more imminent from increased competition and the progress of science—so soon must the "rule-of-thumb" worker encounter unforeseen difficulties.

The manner in which brewing first developed into a trade, and then into a science, proves conclusively the great importance of this vast industry. It would be interesting to trace from early times how in the first instance the brewing of beer was carried on. Regarded rather as a culinary operation than as one necessitating a very special knowledge, it never attained to anything approaching the dignity of the products of the still-room. The preparation of highly-flavoured "strong waters," as they were termed, in which peppermint, cloves, gilly-flower, aniseed, and various other flavourings were mixed and compounded into an infinite variety of curious drinks, absorbed a far larger amount of any critical acumen existing at the time than was accorded to the brewing of the household beer. The brew-houses attached to taverns, farm-houses, and country residences, when, indeed the operations were not conducted in the back kitchen or wash-house, were usally under the control of one of the rougher out-door servants, and from these the first commercial brewers must have obtained the earliest rudiments of their practice. How far back brewing was conducted upon a really extensive scale is a matter of less consequence to ascertain, inasmuch as until within the last sixty years brewing for private and domestic purposes produced by far the larger amount of the beer consumed. Whatever may have been the success attained by brewing

for a general sale, it is certain that the quality of the beer brewed, as compared with its price, was not such as to tempt those who rejoiced in their home-brews to save themselves the trouble and care which must necessarily have been bestowed to produce anything drinkable. Even in London, private brewing continued, notwithstanding the successful efforts of the Thrales and others, afterwards assisted by the financial co-operation of some of the richest of the mercantile community; and within the last fifty years many a bushel of malt has been mashed in tubs very similar to those of the laundry, within a stone's throw of some of the largest breweries.

It would be curious, if we were able, to compare the results of these small hap-hazard operations, conducted under every possible disadvantage, with the beers brewed by means of the best skill then attainable. One thing, however, is certain, and that is that the producers of the home-brewed ales never believed in the superiority of any beverage they could purchase; and if the beer obtainable from large breweries was not superior to the home-brewed ales of the present day, it is equally certain that public brewing must have made vast strides in the improvement of quality, especially in the lighter ales.

In these early days, strong, heavy, rich ales were believed in both by the public and private brewer, for they afforded the greatest then known security against acidity; and, possessing great keeping qualities, plenty of time was allowed for the beer to get into condition before it was put forward for sale or consumption. Darkness in colour was no objection, and in its different stages, from being heavy and saccharine to the development of the peculiar ethers, flavours, and sometimes acidity, to be found in "old ales," a far greater range of taste could be satisfied than is even now the case, with any other single class of beer.

The taste for these old vatted ales has been gradually disappearing for many years, until at the present time it only survives in a few remote districts, where the vast quantity of excessively acid cider still consumed accustoms the public palate to the excess of acidity usually found in the class of ales I am speaking of.

While these old ales have been going out of favour, the public taste has become from year to year more exacting as to the condition and flavour of the lighter and newer ales which have replaced them. The general good quality of the light ales now produced throughout the country, is a proof that the skill of the brewers has kept pace with the requirements of the public, and the enormously increased consumption is a great encouragement to them to make still greater efforts to insure a steady production of beers uniformly perfect, both as regards soundness, flavour, brilliancy, and condition.

Private brewing has lately received an artificial stimulus, owing to being specially favoured by the fiscal changes made in 1880, but although a few private brewers may succeed, under favourable circumstances, in producing drinkable beer, by far the larger quantity brewed must always be of most inferior quality, so that private brewing, if placed on an equal footing as regards fiscal charges with public brewing, would quickly and inevitably die out.

This is a matter that deserves and is receiving the attention of brewers, and no opportunity should be lost of pressing on the notice, both of the Government and of the public, the extreme unfairness of the present regulations, by which a few favoured individuals are enabled to escape their share of the burden of taxation, for no conceivable reason, except the caprice of a Government, which seemed always on the watch for opportunities of injuring the public brewer.

Something will be gained by an attempt to glance at the objects a brewer now has in view, after which we can proceed to the consideration of the means by which these may be most easily and certainly attained. From a general point of view, I take the chief objects of the modern brewer to be the production of a beverage that is wholesome and pleasing to the palate, nose, and eye, and such as will maintain these qualities for a sufficient period without deterioration. It is imagined by many that if beer is brewed from malt and hops alone it must necessarily be wholesome, but this is by no means the case. If either the malt and hops or the water are of bad quality, or if the process is carelessly conducted, a beer will be produced which cannot be considered as wholesome while new, and which will become rapidly more and more unwholesome on keeping. On the other hand wholesome and nutritious beer of first-class quality can be brewed from a mixture of malt with unmalted grain, and other saccharine producing substances, if the manipulations are conducted with the requisite care and skill.

To return to the characteristics of a good beer. Brilliancy of condition not only pleases the eye, but, when naturally induced, is one of the best evidences of successful brewing. The palate, following the impression of the appearance, requires, in addition, that the beer shall be well charged with carbonic acid, and retain it. In a negative sense the total absence of unpleasant flavours, especially those produced by bad yeast and want of cleanliness, is insisted upon by every refined taste, and is of itself of considerable dietetic importance. A pretty general consensus of opinion demands a sufficiency of body without excessive sweetness, and the fine aroma of the hop with its pleasant genial bitter, which should immediately leave the palate clean, without any excess of harsh or otherwise unpleasant bitter.

Such are the general characteristics of good beers, and they will be found, modified within certain limits, to be essential to the successful brewing of the most opposite descriptions of malt liquors. A due balance of fulness and alcoholicity, of saccharine and bitter flavour, is as indispensable in the lightest pale ales as in the strongest beers, whether mild or bitter. The same is equally true of the heaviest stouts and lightest porters. However various the tastes of the upper and lower classes, as manifested in their selection of beers in different localities, the malt liquors in which such characteristics are found developed in their highest perfection are those which have stood the test of the longest experience, and made for themselves the most enduring reputation, so as to enhance the demand for beers of their own peculiar type.

The annals of brewing have conclusively shown that the uniform production of the best beers, whether cheap or expensive has always afforded the most gratifying commercial results. We have now to consider the most appropriate means of ensuring, not only the best results, but also the maintenance of the nearest possible approach to uniform quality; for, be it well understood, nothing can be more detrimental to the interests of any brewery than the occasional sending out of beer of superlative excellence, as contrasted with a general average of a mediocre character, varied by a not unfrequent delivery of decidedly bad beer.

The subject-matter will be, perhaps, best divided under three heads. The first comprises the plant, the proper arrangement of which is of even greater importance than the mere elaboration of details. Beers of the very highest class can undoubtedly be brewed with an adequate plant of the simplest construction, if the arrangements are sufficiently perfect. On the other hand, the most costly, ingenious, and complex machinery and apparatus will not ensure the

possibility of the production of a reliable and always saleable beer. So far is this from being the case, that I regard simplicity of arrangement as being the most important safeguard against many of the evils incident to brewing, while I have been frequently enabled to trace supposed inherent defects to undue complications of arrangement of plant. At the same time, the real merit of modern improvements in the plant and machinery must be fully recognised, and will be duly considered, not only with regard to their bearing upon the improved production of beer, but also as effecting true economy.

The materials used in brewing will be dealt with as comprehensively as possible under the second head, and the third section will be devoted to the description and critical examination of the actual process of brewing.

In the introduction to my original treatise on brewing I promised my readers to give in conclusion a *résumé* of the general subject from a more scientific point of view, so as to explain the relation between the most advanced theories, and their practical application, in such a form as to render them available to those who wish to assume the foremost position in the applied science of brewing. This promise was I fear very inadequately fulfilled, other engagements having prevented me from giving the time to the work which was necessary for the due elaboration of the subject.

In the present edition I have determined to pursue a different plan, and to divide my subject into two distinct parts, each complete in itself.

The first part will include the three heads of Plant, Materials, and Process, and in it I shall endeavour to give as fully as possible all the information which it is absolutely necessary for the practical brewers of the present day to acquire. In fact, this part will treat of Practical Brewing, or in other words it will be Brewing Practically Considered.

In this first part I shall only touch on the more theoretical and scientific subjects connected with brewing, in so far as a knowledge of them is indispensable to the intelligent working of the brewery.

Later on I hope, in my second part, to really fulfil the promise quoted above, from the introduction to my first edition. In it I propose to borrow freely from recent researches on starch and its transformations, on fermentation and the organisms which produce and accompany it, and to endeavour to trace the relation between the scientific facts and the practical results, as we find them in the brewery.

In this second part I hope also to give a series of original photomicrographs and also some remarks on the use of the microscope in the brewery; and in fact to make it as fully as possible correspond with its title of Scientific Brewing, or Brewing Scientifically Considered.

If this my first part is favourably received by the brewing world in spite of its numerous imperfections and short-comings, I shall feel encouraged to devote my time to the somewhat arduous task I have set myself, and to endeavour to complete my second part as early as possible, trusting that the same kind indulgence will be extended to it also.

I trust that all the kind friends who have assisted me in completing this first portion of my work, will accept my most sincere thanks for their co-operation, and I must especially acknowledge my debt of gratitude to Mr. Walter Ramsden for his invaluable assistance in revising the engineering portion of my subject; to Mr. Charles H. Jolliffe for the able manner in which he has helped me with the chapters on the materials and process; and to Mr. Palm for kindly revising my description of the decoction system of mashing.

CHAPTER I.

GENERAL ARRANGEMENT OF THE PLANT.

NO one who has inspected large numbers of the breweries of this country can fail to have been struck with the extraordinary diversity of the arrangement of the plant, and the want of any general agreement amongst those who have erected the breweries as to the objects to be attained, or the best method of attaining them.

No doubt, in many of the older breweries, and especially in those which have grown gradually from small beginnings into large concerns, there is no pretence of anything like a scientific arrangement of the plant, and, indeed, in many cases this could scarcely be expected. But it is most extraordinary how seldom a really well-arranged brewery has been erected, even when no expense has been spared, when there has been ample space at command, and when experienced architects and engineers have been employed.

In arranging the plant and construction of a brewery many local considerations, such as the space available in proportion to the size of plant required, and the utilisation of old buildings, &c., have frequently to be taken into account. These vary in every instance, and

must be met as they arise; but supposing an entirely new brewery has to be erected, there are two main systems of construction, either one of which may be adopted, or some modification intermediate between these two systems may be preferred. Special advantages and disadvantages appertain to each of the above systems, and to all their modifications, and these I will now proceed to consider. The two systems are, first, what is generally known as the Tower system, and, secondly, what I propose calling the Horizontal system.

On the Tower system, when fully carried out, the water is pumped direct from its source into the cold and hot liquor backs at the top of the building, which is of a sufficient height to obviate the necessity for any further pumping of either wort or beer. On this system therefore, the water flows to the mashing machines and mash tuns, the wort from the latter to the underback and coppers, the boiled wort to the hopback, and thence successively to the coolers, refrigerators, fermenting tuns, cleansing casks, and settling backs and thence into the trade casks.

The advantages of this system were so obvious that when first introduced it was eagerly adopted by a large number of brewers, and it is still very generally advocated by those who have had no practical experience of its defects.

The great and manifest advantages of the Tower system are, the much shorter length of pipe required for conveying the wort and beer from one portion of the plant to another, and the entire suppression of the wort and beer pumps. As dirty pipes and pumps are probably the cause of half troubles in a brewery, the suppression of the latter and reduction in length of the

former, are advantages which every brewer will at once acknowledge. What then, are the disadvantages which have prevented the universal adoption of the Tower system, and have caused it to be disliked by most of those who have had much experience of Tower breweries? The disadvantage which is immediately apparent to the brewer from the first day he takes the general supervision of a Tower brewery, is the enormous number of stairs, and the physical impossibility of ascending and descending them more than a certain limited number of times daily. It is all very well first thing in the morning, for the mash tun is in a snug little room, and the hot liquor back in convenient proximity to it; but later on in the day his attention is required in three or four different departments within a few minutes, and then he realises the absolute impossibility of seeing that the sparging and running off of the worts is being properly attended to, the tunroom men doing their duty, and that at the same time the racking and loading up is not being neglected.

But besides the difficulties of supervision, it is a serious objection to this system that the cost of any alterations of or additions to the plant is greatly increased, and also restricted within very narrow limits. A Tower of even small dimensions is a costly structure, and everyone is therefore inclined, to restrict its size and consequent cost as much as possible. When once the Tower is erected it cannot be enlarged except at an enormous expense, if therefore the trade extends so as to exceed its capacity, it is for all practical purposes a new brewery that has to be erected.

I have dwelt thus fully on the demerits of the Tower system, because at first sight it is so captivating. I will

next consider what are the chief advantages and disadvantages of what I call the Horizontal system.

The brewery in this case consists of a long building of two or more stories, or of several such buildings placed side by side. The wort has to be pumped twice; first from the underback to the coppers, and a second time from the hopback to the coolers. The latter must be placed at such a height as will command the refrigerators, and the refrigerators the fermenting tuns; and if the system is adopted of cleansing into unions, the half-fermented beer must also be pumped to them.

I think the best arrangement, and one which should always be adopted where a suitable piece of land can be obtained, is as follows :—

Two buildings are erected side by side, the height of the main walls of which need not exceed 25 feet for a plant of 40 or 50 quarters ; the width of each building being about 30 feet. I will call these two buildings No. 1 and No. 2.

In No. 1 there is first the pump room, with hop stores above; secondly, the mash tun room, with underback below, and with the grist cases, converter, and hot liquor back, above the mash tuns; thirdly, the engine room and mill room below, with malt stores above ; and, lastly, the fermenting tun room, with racking room below. If cleansing into unions is adopted, the union room forms an extension of the fermenting tun room, a centrifugal pump raising the beer from the tuns, to the unions, which are all on the same level.

In No. 2 building I place the hop back first, in a line with the pump room in No. 1. Then come the coppers, stoking hearth, and steam boilers, and lastly, the cask

washing and cooperage departments, which thus run parallel with the racking room in No. 1.

In No. 2 building, above the steam boilers, I place the coolers or wort settling back at a high enough elevation to command the refrigerators, which latter command the fermenting tuns in No. 1 building.

The two cold liquor backs form a portion of the roof, but are themselves covered with a light roof of galvanised iron.

Above a portion of the cask washing shed is a large hot liquor back at a sufficient elevation to command the fermenting tuns. The hot liquor from this back is used for washing the tuns, casks, &c., &c., and the water from the refrigerators and attemperators is utilised, as far as possible, for the supply of this back.

In the fermenting room I erect a cold liquor back to supply the attemperators only, and both the brewing hot liquor back, and this attemperating cold liquor back, I supply direct from the rising main of the water pumps.

The immense advantages, as regards convenience of working, possessed by this Horizontal system are manifest, for the brewer has everything under his eye, and every portion of the brewery is accessible to him on the easiest terms.

From the mash tun room as his centre of operations, he can step direct on to the copper stage, and a short passage partitioned off from the malt store conducts him into the fermenting rooms, with the racking room below.

Another advantage of this system of construction is, that by excavating the space under the two buildings, larger and better cellarage is secured than it is possible to obtain below breweries built on other systems.

The question is, what are the disadvantages of this system? Well, I think they may be summed up as consisting in the necessity for having two or at most three additional pumps, and a considerable extra length of wort and beer mains. Now, if it was impossible to keep these pumps and mains clean, I should say at once that these objections were fatal; but the fact is nothing is easier than to keep pumps and mains clean, provided they are properly erected. All that is necessary is, that every time they are used they should throughout their whole length be rinsed with clean hot water, and steam then blown through them. Of course, proper steam and water connections and outlets must be fitted to the mains, which must be so arranged that the water and steam will pass through every inch of them; but if this is done, one man or even a boy can effectually wash and steam every main in a large brewery in the course of an hour or two at the outside.

Rotary, or centrifugal pumps should in all cases be used for wort and beer, and these pumps should be placed below the level of the liquid to be pumped. Rotary and centrifugal pumps are now made of such an excellent construction, that no brewer who has once tried them will go back to the old three-throw pumps, at any rate, for wort and beer. In fact, the three-throw pumps should only be used where the level of the liquid to be pumped is below that at which the pump can be conveniently placed, as in the case of water from wells, borings, &c.

The only system intermediate between the Tower and Horizontal constructions, that calls for any special notice, is that in which the mash tuns and underback command the coppers, and the boiled wort is pumped

from the hopback on to coolers, which are placed at such an elevation as to command the fermenting tuns, which again command the unions, and the unions the racking squares. Only one pumping of the wort is necessary on this system, and that the boiled wort. The necessary elevation of the buildings is somewhat considerable, but not nearly so excessive as on the Tower system. The mains are very simple, and the whole available space in the buildings easily utilised.

I need not dwell on the details of this form of construction, as they will be evident at once to every brewer. The most notable instance is Messrs. Allsopp and Sons' splendid brewery, adjoining the Railway Station at Burton-on-Trent. The old brewery in the High Street belonging to the same firm is on the Horizontal construction, as are most of the other breweries in that well-known centre of the brewing trade.

CHAPTER II.

WELLS AND WELL SINKING, AND WATER FILTRATION.

WHEN a well is about to be sunk, the first thing to be determined is the strata through which it will have to be carried. Valuable general information can generally be obtained from the geological maps of the district, and further particulars can often be gleaned by enquiries as to the strata passed through in sinking other wells and borings in the neighbourhood; but it is nearly always advisable to sink a trial boring of two or three inches diameter, so as to obtain more exact information, and also to ascertain with certainty whether a sufficient supply of water can be obtained, at what depth it is reached, and what are its chemical constituents.

It seems so self evident that in choosing the site for a brewery, the possibility of obtaining a good and abundant supply of water ought to be the very first consideration, that it may almost appear impertinent to insist upon this point, but I have so often come across instances in which heavy loss has been incurred by the neglect of this precaution, that I must dwell upon its absolute necessity.

The presence of an abundant supply of water having been ascertained, and its quality proved to be satisfactory by careful chemical analysis, the third point to decide upon is how to secure the supply in its full abundance and purity. I will therefore next consider the various methods by which this may be accomplished.

The well-known Abyssinian tubes are probably the best and simplest means of obtaining a supply of pure water, where this exists at a moderate depth; but, unfortunately, their application is somewhat limited.

In the first place, the depth to which one of these tubes can be driven, even under favourable circumstances, rarely exceeds fifty feet. And, in the second place, these tubes can only be driven in moderately soft strata, and those that are free from boulders or other large masses of rock.

The method of driving tubes is so well known that it needs no description here.

When circumstances will not allow the use of the Abyssinian tube, an ordinary boring, a dug well, or both combined, must be resorted to.

In all cases in which the water-bearing strata are at a considerable depth, and the water rises to within about twenty feet of the surface, with sufficient rapidity to supply the maximum amount required, the simple boring is the best and cheapest arrangement. If a good and permanent job is required, the boring must be lined with heavy wrought iron lap-welded tubes, of about half an inch in thickness, screwed firmly together. The external portion of the end of these tubes with the male screw on it, is cut away to half its thickness, and also the internal half of the end with the female screw; so that when the tubes are screwed together, the cor-

responding male and female screws being of exactly the same length, the remaining thickness of the ends butts against the solid tube, and the whole forms a pipe uniformly smooth inside and out, and that can be driven as securely as if it had no joints whatever.

All other varieties of tube are quite untrustworthy, being liable to split, or the screws to strip, when any force has to be used in driving them; and unless the bore tube is driven very tight through the boring, there is no security that impure surface water will not find its way down along the outside of the tube, and contaminate the deep spring. The reason why so many tube wells yield an impure water, is either that the tubes, being of bad make or too thin, have split during the driving, or because the tube has not been driven tight enough into the bore hole, or, lastly, because the tube has not been carried far enough down the boring. As a rule the boring should be tubed throughout its whole length, until good solid rock is reached, and the tube should be driven for some feet into the rock. Chalk does not generally require tubing, but neither marls nor clays, however hard and firm, are safe unless lined.

When the water does not rise near enough to the surface, or when it does not come up in sufficient quantity, and a reservoir must therefore be formed, a dug well in addition to the boring becomes necessary. These wells must be lined so as to exclude the surface water; and the best and cheapest lining consists of cast-iron cylinders, well jointed by means of internal flanges bolted together, with a good layer of hemp gasket soaked in hot tallow between them, and the head of each bolt surrounded with a grummet of the same material.

These cylinders are driven down as the excavation

proceeds, the lower end of the bottom cylinder being formed with a cutting edge in order to facilitate this operation.

This cutting edge is finally driven into the impervious stratum, which should in all cases form the bottom of the well. When the well is completed, and before the boring is commenced, the former must be proved to be absolutely water-tight, which is easily ascertained by seeing that no water collects in the well after it has remained untouched for say twenty-four hours. The boring is then commenced and carried down to the necessary depth.

Ordinary dug shallow wells have still to be sometimes resorted to, although the Abyssinian tubes should be substituted for them whenever the local conditions will allow.

In the chalk formation, and also in rock, dug wells can be constructed very cheaply, as no steining is required after the solid chalk or rock is reached. In such wells the superficial strata should be removed down to the solid rock or chalk, and to a diameter three feet larger than the finished well. Then from the solid chalk or rock up to the surface, nine inch brickwork should be carried, and nine inches of clay well puddled in at the back of the bricks as the work proceeds, so as to perfectly exclude all surface water. The top eighteen inches or two feet of the brickwork should be laid in cement.

When the well has to pass through stratifications of too friable a nature to admit of the above method, the drum or sinking curb becomes indispensable. The simplest and cheapest form, but by no means an efficient one, is the wooden drum curb, which is a stout cylinder

of wood, supported internally by wooden curbs, to which the planking is strongly nailed ; the lower edge is fastened firmly to a stout iron hoop ; this drum is loaded with dry brickwork, built up so as to form the sides of the well, and is sunk as the excavation proceeds, care being taken by means of plummets to keep it vertical. There are great objections to this curb, both from the wood decaying after a time and contaminating the water, and still more from the impossibility of keeping out the impure surface or other waters from a well so constructed.

Formerly the solid brick and cement sinking curb was used to obviate the above faults, but the cast iron cylinders already described, are now exclusively employed, and are certainly the cheapest and best form of sinking curb. A well formed of such cylinders, can be rendered perfectly safe from all surface infiltration, if proper precautions are observed. The iron cylinders are not usually carried up to the surface of the ground, but only to a short distance above the surface springs, the upper portion of the well being completed with brickwork laid in cement, or puddled with clay.

I have been somewhat particular in describing the various methods of well sinking, as this is a matter too often left entirely to the discretion of the local well sinker. It is comparatively easy, in the first instance, to adopt such means as will ensure a good tight well, but very difficult to correct any fault of original construction.

When from any cause there is, unfortunately, an infiltration of surface or other objectional water, or when the brewing water is derived from rivers or reservoirs, filtration is essential. If the water is supplied by public companies carrying out an efficient system of filtration,

the filters of the brewery need only be provided for the emergency of occasional imperfection in the company's arrangements. But when the comparatively impure water comes unfiltered to the brewery, nothing less than the most perfect system of filtration will render it safe to use for brewing purposes.

Experience has now proved that the water supply of even the largest breweries can be perfectly freed from present organic impurities by Rawling's Patent Animal Charcoal Filters, and when the water is free from mechanical impurities these filters are alone required. When, however, the water is not only impure but muddy, sand or coke filters of sufficient capacity must be employed to remove all solid matters, which would otherwise choke the pores of the char, and render it inactive.

Some filters are advertised as remaining active for long or even unlimited periods without any change of the filtering medium. All such assertions must be regarded with incredulity, for it has been practically proved that all filtering media lose their efficacy in a comparatively short space of time.

Animal charcoal, specially prepared by careful washing and reburning, is the best and most efficacious of all filtering media, and experience with it in the filters I have named above, and in which its powers are fully utilised, proves that it will retain those powers for periods varying from two to six months, according to the amount of impurity in the water. In most cases a fresh charge of char is required either three or four times a year when the filters are in daily operation. The largest filters yet erected on this system are capable of purifying from 150 to 200 barrels per hour.

CHAPTER III.

PUMPS AND MAINS.

IN the ordinary process of brewing the first operation is to raise the water from its source to the vessel in which it is to be heated ready for mashing. I shall therefore commence my consideration of the brewing plant by alluding to some of the principal varieties of pumps, and more especially to those which I consider best adapted for brewing purposes.

The following is a list of the most important forms of pump at present in use :—

The lift pump.
The lift and force pump.
The three-throw lift and force pump.
The double action pump.
Donkey pumps with fly wheels.
Donkey pumps without fly wheels.
The rotary pump.
The centrifugal pump.
The chain pump.
The pulsometer.
The various forms of water elevators on the injector principle.

The simple lift pump is too well known to require any special description. Its simplicity and cheapness recommend it for house and farm purposes, where the water is obtained from shallow wells, but it is not adapted for breweries, except perhaps those of the very smallest size. There is, however, a variety of this pump commonly used in mining districts for raising the water from the bottom of the shafts. In this form the barrel is placed within easy reach of the water, and lengths of pipe are jointed on to the top of the pump barrel upwards, until they reach the level at which the water is to be delivered. The piston rod passes up through the whole length of these pipes, and is raised and lowered by a crank with a heavy counterpoise, so as to balance the great weight of the pump rods, and equalize the action as far as possible. This is a simple but very clumsy arrangement, a modification of which may, however, be usefully employed when it is necessary to raise water from near the bottom of a large boring, in which it does not rise to near the surface, and where there are difficulties in sinking a well to within reach of the water.

The single-barrelled lift and force pump is as well known and needs as little description as the lift pump; almost every house above the size of a day labourer's cottage, and not supplied by a water company, depends on this pump for its water supply. It is an excellent hand pump, but owing to its throw being intermittent, it is not adapted for driving by power.

The three-barrelled lift and force pump, commonly known as the three throw pump, overcomes the above objection to the single-barrelled lift and force pump, and is more commonly used for all purposes in the

breweries of this country than any other pump. The three barrels working alternately, especially when assisted by an air vessel on the rising main, secure a fairly equable flow through the latter, and this pump is equally adapted for working at the bottom of a deep well, or for raising liquids within the brewery. The objections to this form of pump are twofold, for in the first place, as it has to be driven from a shaft, the main brewery engine has to be kept at work the whole time it is in operation; and secondly, owing to its system of valves it cannot be so thoroughly cleansed by steaming, as the valveless rotary and centrifugal pumps, and it is not, therefore, so well adapted in that respect for pumping wort and beer.

Donkey pumps, in which steam driving cylinders are combined with the pumps, are free from the first objection I have mentioned above. They only require connecting with the steam boiler by means of a wrought iron pipe of one or two inches in diameter, and can be started at any moment without interfering with the large engine or other machinery.

These donkey pumps are of two principal descriptions, viz., those with fly-wheels and those without. The latter are perhaps theoretically the most perfect instruments, but for practical purposes in the brewery I greatly prefer the fly-wheel pumps.

I have used large numbers of these fly wheel donkey pumps, by good makers, and they have never given me any trouble. They will stand the rough usuage to which they are liable in the hands of careless and unskilled labourers, and if at any time through excess of illusage, any part of them is broken, it can be quickly and cheaply replaced, for each part is made to a fixed

pattern, which can be purchased separately, and fitted, so as to replace the broken part by the brewery workman without calling in skilled assistance.

There are several makers who turn out excellent donkey pumps, but this is not universally the case, and I must warn brewers only to purchase from firms they can depend upon, for bad donkey pumps are dear at any price, being a constant source of loss, annoyance, and expense. I speak feelingly, and from long experience on this matter.

In choosing a donkey pump it must always be borne in mind, that it requires an air vessel both on the suction and rising mains, and one frequent cause of the imperfect working of these pumps is the omission of one or both of these air vessels.

The donkey pumps, without fly-wheels, and by the best makers, are really beautiful pieces of mechanism, but unless the brewer keeps a skilled mechanic on the premises, he had better have nothing to do with them. I am alluding here more especially to the smaller sizes of these pumps; I believe the large sizes, by the best makers, are more satisfactory from a practical point of view.

The best forms of rotary pump are most useful and convenient, and have been too long neglected by brewers. I cannot recommend the single spindle forms but those with two spindles, and especially those known as double cog-wheel pumps, are excellent. In fact, for pumping wort and beer, I consider these pumps superior to all others. They work equally well at either a slow or fast speed, they occupy very little space, and if well made, are very durable, and not liable to get out of order.

The most important advantage, however, of these rotary pumps for wort and beer, is that having no valves they can be steamed as easily and perfectly as the pipes themselves, and as there are no inside cavities, which are not passed over by the moving parts, they naturally tend to keep themselves clean, which is what certainly cannot be said of any other form of pump.

The original form consisted simply of two ordinary cog wheels, revolving in an elliptical box, so that the teeth geared together in the middle. These cog wheels revolved in contact externally with the semi-circular surface of the box, and with its flat sides through which the spindles were passed.

The newer forms have only either two or four teeth, so shaped as to produce as far as practicable a rolling motion of one tooth over the other one gearing into it, and the friction is thus greatly reduced. The inlet and outlet pipes are on the opposite flat portions of the elliptical sides.

The action of these pumps is very simple, and consists in the liquid which is forced up between the cogs on the outside, being prevented from returning by the cogs gearing into one another in the middle.

These rotary pumps will not suck for more than a short distance without a foot valve, especially with hot liquids. When used for pumping wort, either from the underback or hopback, the best plan is to fix the pump below the level of the wort, so that the latter flows into the pump, which, although weak in suction power, is capable of lifting to almost any height without requiring to be driven at any excessive speed. With cold liquids, such as beer, these pumps may be relied upon to suck about three feet of vertical height. When

fitted with a foot valve, their suction power is greatly increased.

Rotary pumps are not adapted for pumping liquids containing grit, as this soon cuts up the working faces. They are not, therefore, well adapted for pumping water from wells or springs, as traces of sand are always liable to come up with the water, their weak suction power also unfits them for this purpose.

Centrifugal pumps are too well known to require description. For some purposes they are simply invaluable, but their use is somewhat restricted, not only by their weak powers of suction in which they resemble the rotary pumps, but also by the very special mode in which they act.

In the case of all the other pumps that I have hitherto mentioned, the amount of liquid thrown is pretty nearly proportional to the speed at which the pump is driven, and even at a very low speed some liquid is raised to the required height. This, however, is not the case with centrifugal pumps; a certain speed is required for a certain height, and this speed rapidly increases with the height. If this necessary speed is not attained the flow of liquid thrown does not merely diminish but ceases altogether. The practical effect of this peculiarity is that these pumps are not adapted for raising liquids to great heights. But for raising thick liquids, to moderate heights, these pumps are better adapted than any other form.

Thus, in the Lager beer breweries, mashing on the German or decoction plan, the mash itself is rapidly and freely transferred from one vessel to another by means of one of these centrifugal pumps. In the same way in breweries using Pigeon or other converters, the contents

of those vessels may be transferred without risk or trouble from the converter to the mash tun, in cases in which it is found more convenient to place the former vessel at too low a level to command the latter.

Centrifugal pumps should also be used in all cases in which beer has to be pumped which is in a state of fermentation, and therefore containing an abundance of yeast cells. There is no practical risk of injuring the yeast and interfering with the fining of the beer when these pumps are used, for there are no surfaces in them working in contact with one another, and consequently liable to crush the yeast cells.

Centrifugal, like rotary pumps, can be kept perfectly clean by washing and steaming, and are therefore well adapted for use in breweries, and specially in those constructed on the Horizontal system, for on this system a good many pumps are required to pump both wort and beer, and it is essential that these pumps should be capable of being perfectly cleansed by simply rinsing and steaming them, while on the other hand they are not required to lift to any great height.

The other varieties of pump that I enumerated at the commencement of this chapter are not of much interest to brewers.

Chain pumps are sometimes used in small maltings, and in exposed situations, as they are not liable to injury from frost.

The Pulsometer, and also the injectors, are not adapted for breweries, as the steam used for the motive power is condensed in the liquid raised. This increases the temperature so that refrigerating water must not be raised by this means, and no brewer wishes to mix condensed steam with either his mashing water, wort, or beer.

The hydraulic ram is a most interesting and useful means of raising water, but unfortunately it only works well when on a small scale, and is better adapted for farm use than for breweries.

I will conclude this chapter with some suggestions as to the pumps best adapted for use in the various brewing operations.

For pumping water from depths of less than twenty-five or twenty-six feet, Three Throw Pumps and Donkey Pumps are the best forms.

For raising water from deep borings the Lift Pump, commonly used for pumping out mines, or some modification of it, can often be used with advantage.

For deep wells the Three Throw Pump stands pre-eminent as certainly the best adapted for the purpose; and I will here describe a special modification of this pump, which, for this purpose, possesses the great advantage that the bucket and valves are always accessible however high the water may rise above the pump barrels.

In this form the barrels of the pump are fixed at or near the bottom of the well, and each barrel is prolonged upwards by a stand pipe, which reaches to well above the highest point at which the water ever rises in the well. The top chamber of the pump is fixed on the top of the stand pipes so that by removing the covers the working bucket can be withdrawn. A hook can then be passed downwards until it engages the bale of the bottom bucket, which can then be raised by means of this same hook. All the working parts of this pump are therefore as accessible when it is at the bottom of a deep well, as those of an ordinary pump are when fixed at the surface.

When it is necessary to increase the suction on the spring, the suction mains of these deep well Three-Throw Pumps can be carried down the bore pipe to a depth of about thirty feet.

It is a common practice in breweries to use Three-Throw Pumps for raising wort and beer, but for these purposes rotary and centrifugal pumps are far better adapted, on account of the greater ease and certainty with which they can be kept clean.

For raising wort or beer to a height of more than twenty or thirty feet, the rotary pump should be used, but for lower lifts both the rotary and centrifugal are equally adapted. For pumping beer during fermentation the centrifugal is undoubtedly the best pump, and in this case a high lift can never be necessary.

For pumping thick mash, such as the contents of converters, the contrifugal pump is the only form available.

In many breweries it would be convenient to use automatic or Steel's mashers, but the low level at which the mashing water stands in relation to the mashing tun, renders this impossible. In such cases a good rotary or centrifugal pump may be used to give the stream of water sufficient force to allow of a Steel's or Automatic masher being used. In this way also in old breweries, where it is very advisable to increase the supply of mashing water, the new hot water back may be placed even at the ground level, in any spare corner, and the water raised by means of a rotary or centrifugal pump.

In erecting pumps it must be always borne in mind that the extreme height from the level of the liquid to be pumped up to the lower valve is for simple lift pumps, for lift and force pumps and for plunger pumps, 25 ft. For rotary pumps, with cold liquids and without a

foot valve, 3 ft. For rotary pumps, with hot liquids, and for centrifugal pumps, the liquid should always be on a level with or above the pump. With a foot valve these latter pumps have a certain amount of lifting power, but the foot valve is objectionable when the pumps are used for the purposes I have indicated.

In deciding on the number of pumps to be used in a brewery, there is one consideration which should never be lost sight of, and that is that the cold water pump must be used for nothing else but pumping water, and, if besides the pure water used for brewing, a more or less impure water is used for refrigerating and attemperating purposes, there should be two pumps, one for each class of water. With proper precautions one set of pumps may be used for both boiled and unboiled wort, but it is much more convenient, and far safer to have separate pumps, one for the raw wort, one for the boiled wort, and another, again, for the beer if that also requires pumping.

Mains for beer and wort should be always made of tinned copper pipe, with gun metal flanges and caps, and all T pieces should be formed of tinned sheet copper, with smooth surfaces and easy throats.

Water pipes may be made of cast or wrought iron, but lead pipes are not adapted for brewery use, and should be entirely excluded from breweries.

Thermometers should be inserted in the hot water mains supplying the mashing machines, mash tuns, and spargers. They should be placed in such positions as are most convenient to the brewer, and where at the same time the full flow of the water comes in contact with the bulb of the instrument. Fixed thermometers are also sometimes useful in the pipes from the spent taps.

CHAPTER IV.

COLD WATER TANKS AND MAINS.

THE tanks to hold the cold water to be used in a brewery may be made of a variety of materials, among which I may mention wood, copper, lead, zinc, wrought iron, galvanized wrought iron, and cast iron.

In a brewery the water is used for such a variety of purposes, that I cannot think the common practice of having only one tank to supply the whole is a commendable one, and now that tanks can be so easily obtained, and at such a moderate cost, there is the less reason for adopting it.

Every brewery should, in my opinion, have at least two cold water tanks, one for storing the brewing water, and a second for the water used for other purposes.

I much prefer having a third tank also in addition to the above, for the special purpose of containing the attemperating water.

In the case of those tanks which are to contain the water to be used in mashing and sparging, the essential requisite is that they should preserve it in the most perfect condition as regards purity; the material of which they are composed must therefore be of such a nature that it is not acted on by the water. The surface

of the tank must be capable of being easily cleaned, and its shape must be such as to render it easily accessible, at the same time that every part can be seen at a glance, so that the brewer may assure himself that the cleaning has not been neglected. A light roof should be erected over the tank, especially in the case of breweries situated in large towns, and in the vicinity of chemical works, or where leaves or other refuse is liable to be blown into an uncovered tank. In every case care must be taken to exclude all drainage or drip from any contiguous roofs, to keep the water pure and unmixed as it comes from the well, and to place the tank in a light and easily accessible situation, where its condition can be ascertained at all times and without difficulty. As regards the materials of which the tank should be constructed, a wooden tank if properly made will answer well for a certain number of years, but sooner or later decay must commence, and then it becomes altogether unfitted for the above purpose.

Wood lined with copper makes a most unexceptional tank, but entails a large and unnecessary expense. Lead is so liable to be dissolved by water, that it can never be considered a fit material for lining tanks intended for storing water which is to be used for dietetic purposes. Zinc forms a very good lining for a tank if the sheets are heavy enough. Nothing less, however, than No. 14 gauge should be used, and it is advisable to make the bottom of even somewhat thicker sheet. In all these lined wooden tanks the wood should be well painted or tarred.

Wrought iron is so quickly acted on by water, especially when as in a tank, it is alternately wet and dry, that I do not consider it a suitable material for

containing brewing water. The scales of rust which form on the surface of the wrought iron are non-adherent, and as the corosion proceeds these scales peal off, leaving an uneven surface, which it is difficult to keep clean.

Ordinary paint, mixed with linseed oil and turpentine, affords but an imperfect protection against oxidation. Some spirit varnishes have much greater protective power when applied to wrought iron than ordinary paint possesses ; but these spirit varnishes, to be really effective, require the aid of a somewhat high temperature to render them permanently adherent, and their application is, therefore, troublesome.

Small iron tanks, galvanized after they are put together, are useful for many purposes, but cannot be made of the size required to contain the brewing water, for any but the smallest breweries.

Cast iron is, perhaps, the only material that can be used for the construction of the tanks that are to contain the brewing water, which is at the same time cleanly, indestructible, and of moderate first cost. Cast iron is naturally coated with a layer of carbide and silicate of iron, which has a remarkable power of resisting oxidation. If this outer skin is removed, the liability to oxidation is considerably increased, but under similar circumstances cast iron will never oxidise with the same rapidity as wrought iron. Even when an oxidised coating forms on cast iron, it adheres with considerable tenacity, so that under all circumstances cast iron possesses great advantages over wrought iron in this respect. Cast iron tanks being composed of a number of panels bolted together, it is necessary to provide very rigid supports to carry them, and the supports must be

equally unyielding on all sides, or the tank will not remain water tight. Solid walls and iron girders, with brick, stone, or iron pillars, are the only proper means of supporting these heavy tanks.

The panels of cast iron water tanks are held together by means of bolts passing through the flanges, which are cast on the four sides of each panel. There are several ways in which the joints are rendered water tight. The old plan was to keep the flanges a short distance apart, by chipping strips or fillets round the inside edges, and then to fill the spaces thus left between the flanges with iron cement well caulked in; this plan makes good tight work, but it exposes a certain amount of rough uneven surface of oxide of iron to the action of the water. A great improvement on the above plan has been introduced of late years by which this objection is entirely got rid of—the flanges of the plates being planed with perfect accuracy, so that they only require a coat of paint, or a piece of very thin india-rubber sheet, interposed between them in order to render the joints perfectly tight as soon as they are firmly bolted together. All brewers' utensils made of cast iron should be jointed in this way, and most excellent tanks of every size and shape can be obtained of this construction.

The outsides of cast iron cold water tanks should always be well painted, and the first coat should be of boiled oil, with a little red oxide of iron paint or ochre added to it to give it some body. The insides of these tanks had better be left unpainted, and only covered with an occasional wash of lime. All metal tanks containing cold water, when exposed to steam, as they generally are in a brewery, have the unpleasant peculiarity of dripping condensed water on everything

below them ; it is well worth while to obviate the unpleasant effect of this perpetual dripping by erecting under such tanks a light roof of galvanized corrugated iron, with gutters to carry off the condensed water.

In the case of those tanks which are to contain the refrigerating and attemperating water, the most important consideration is that the water shall be kept as cool as possible. This is a point that I do not think has received, in most breweries, the attention it deserves; two or three degrees of heat will often make all the difference in the possibility or otherwise of refrigerating and attemperating the beer to the temperature desired, and if a naked metal tank is placed where the steam from the brewery can condense on it, the water will quickly gain several degrees of heat. For this reason, wherever from the nature of the supply of water it is not practicable to pump it direct from the well through the refrigerator, which is by far the best plan, it is advisable to have a separate tank for holding the water that is to be used for cooling purposes. This tank should be removed as far as possible from the heat of the brewery, and it is best made of the shape that exposes the least surface in proportion to its capacity. If from any circumstance it has to be placed where it can be effected by the heat of the brewery, it should be covered over, and either made of a slow conducting material or coated with felt.

Wood, as a slow conductor of heat, is a very suitable material, the drawback to its use being its perishable nature.

Wood lined with metal is much better in this respect, and with felt between the metal and the wood the non-conduction of heat is rendered as perfect as possible.

For the smaller sizes of cold water tanks, wrought iron, galvanised after the tank is put together, is a very suitable material, and if such tanks are clothed with felt they will keep the water as cold as possible, while at the same time they are cheap and durable.

In some breweries the supply of water for the attemperators may be conveniently obtained from the tank in which the refrigerating water is stored; but it is generally better to erect a special tank for the supply of the attemperators only. This tank should be placed in some part of the fermenting rooms, and the necessary precautions, as detailed above, taken to keep the water as cold as possible.

When this special tank for the attemperating water is dispensed with, means should be taken to equalise and moderate the pressure from the main tank, and this object can be most conveniently accomplished by placing a small supplementary tank, only holding a few gallons, and supplied by means of a ball cock, between the main tank and the attemperators.

The adoption of these two precautions, viz., the keeping the water supply to the attemperators as cold as possible, and at a perfectly even pressure, are of the greatest importance, and I have known cases in which their neglect has been the principal cause why brewers have failed in producing ales of uniformly good quality during the warm months.

Having now described the general principles which should govern the distribution and storage of water in a brewery, I will illustrate the subject by describing a special arrangement applicable to a brewery provided with two water supplies, one pure and the other of inferior quality, and with three cold water tanks.

At the close of the last chapter I insisted on the necessity of having two water pumps, one for each of the above qualities of water. In the following description I shall call the pure water pump and the mains connected with it No. 1, and the pump for the impure water with its mains No. 2.

The rising mains of both these pumps are carried up to a sufficient height to command all the cold, and also the hot water tanks, backs. or coppers. The branches given off from these rising mains are as follows.

First, both No. 1 and No. 2 give off branches to the cold water tank placed in the fermenting room for the supply of the attemperating water. Both these branches when they reach the tank terminate in ball valves, that on No. 1 main being fixed so as to close before that on No. 2 main; so that No. 1 water is only used for attemperating when the supply of No. 2 water is deficient.

No. 1 main next gives off a branch to the hot liquor backs, or coppers; which branch is furnished with the cocks or sluices necessary to regulate the supply for each of the above vessels.

Above this No. 1 main gives off a branch of its full diameter for the supply of the pure water store tank. This branch terminates in a ball valve large enough to allow, when open, the whole of the water thrown by No. 1 pump to pass through it.

No. 1 main is then carried upwards to a height of at least five or six feet above the level of the last-named tank, and then terminates in an open end, commanding the main store tank for the No. 2 or impure water.

No. 2 main, after giving off the branch already mentioned to the attemperating tank, gives off a second branch, furnished with a sluice or stop cock and of large

size, to the refrigerators, and above that branch terminates in an open end commanding the store tank for No. 2 water.

The effect of the above arrangements is that the attemperating tank is always kept full of water direct from one or other source of supply. The water for mashing and sparging is also pumped as far as possible direct into the vessels used for heating it. As much as is required to keep the store tank for No. 1 water full runs to it, and the balance flows into the store tank for No. 2 water. The No. 2 water also can be pumped direct through the refrigerators, and what is not used flows forward into the No. 2 store tank.

The above arrangements are all automatic, and no waste of water can occur unless No. 2 store tank is allowed to overflow.

The other cold water mains and connections required in a brewery arranged as above are as follows :—

From the attemperating tank, pipes and connections of ample size to all of the attemperators.

From No. 1 tank, a main giving off branches furnished each with a sluice or stop-cock to supply each of the hot water backs or coppers, and also the attemperating tank, so that a supply of water may be obtained for attemperating from No. 1 tank if all other sources of supply fail.

From No. 2 tank one branch is carried to the refrigerators in order to supply them with water when the pumps are not in operation. A second main from this tank descends to the lowest floor of the brewery and cellars, giving off branches to the attemperating tank, to the Hot washing water tank, and also a branch of large size on each floor. All these branches must be furnished

with sluices or stop-cocks, and on each floor a hose should be suspended in a convenient position, and furnished at one end with a union, by means of which it can be quickly connected with the cold water supply sluice or stop-cock, belonging to the room in which the hose is suspended.

This latter arrangement is not only very convenient for washing down, filling vessels not in use with water, &c., but it constitutes an invaluable protection in case of fire.

Branches should also be provided to conduct the waste water from the attemperators and refrigerators to the Hot washing water tank, so that it may be utilised there as far as possible. These branches must be provided with sluices so that the water can be shut off from the above tank, and when these sluices are closed a T piece with an open branch rising above the level of the tank, allows the water to flow away to waste.

CHAPTER V.

HOT WATER BACKS, COPPERS AND MAINS.

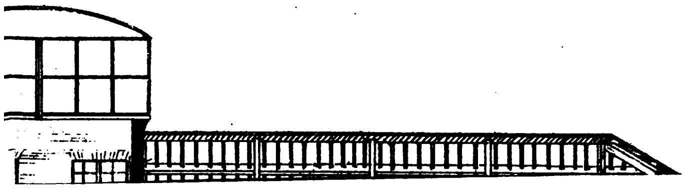
HOT water is used in a brewery both for brewing, properly so called, that is to say, for mashing and sparging, and also for washing purposes. When the hot water is required for washing only it is of very little consequence how it is heated, provided that this is accomplished in the most economical manner and with sufficient rapidity. In discussing the various methods of heating water, I shall therefore devote most space to the consideration of those which are specially applicable to the preparation of the water required for mashing and sparging.

The modes of heating water for use in the brewery may be classed under the following heads, and I shall consider them in the order in which they are enumerated :—

1st. The water may be heated in the ordinary brewing copper by means of a fire placed underneath the copper.

2nd. It may be heated by means of steam driven directly into it.

3rd. A detached boiler may be used, which is heated by a fire, and connected with a tank containing the water by means of circulating pipes arranged for the flow and return of the latter, as in the hot water apparatus ordinarily used for heating buildings.



BREWING:

PRACTICALLY & SCIENTIFICALLY CONSIDERED.

INTRODUCTORY.

THE title of most of the earlier works on my subject was not unfrequently comprised in the words "The Art and Mystery of Brewing," or even if those words were not used, the subject was treated in a manner which closely corresponded with them. My present object on the other hand is so far to avoid the conjunction of such terms, that I shall endeavour to show that the very essence of the one is incompatible with the existence of the other. Perfection in brewing, like perfection in any other manufacture, or, indeed, in any series of complex and delicate operations, can only be continuously maintained by a thorough knowledge of the nature and qualities of all the materials employed, and of the different effects produced by the slightest variation of the working processes.

To whatever extent there is any mystery shrouding the properties of the materials, or any uncertainty in obtaining the desired results, from materials, the properties of which are well known, to that extent is the art and practice of brewing dubious, and liable to entail loss.

The mature judgment of intelligent experience has always done good practical work, so long as the conditions upon which that experience was founded were not materially changed by necessity or expediency. But as soon as the best "rule-of-thumb" brewer is compelled to deviate from the beaten path—and this deviation is becoming daily more imminent from increased competition and the progress of science—so soon must the "rule-of-thumb" worker encounter unforeseen difficulties.

The manner in which brewing first developed into a trade, and then into a science, proves conclusively the great importance of this vast industry. It would be interesting to trace from early times how in the first instance the brewing of beer was carried on. Regarded rather as a culinary operation than as one necessitating a very special knowledge, it never attained to anything approaching the dignity of the products of the still-room. The preparation of highly-flavoured "strong waters," as they were termed, in which peppermint, cloves, gilly-flower, aniseed, and various other flavourings were mixed and compounded into an infinite variety of curious drinks, absorbed a far larger amount of any critical acumen existing at the time than was accorded to the brewing of the household beer. The brew-houses attached to taverns, farm-houses, and country residences, when, indeed the operations were not conducted in the back kitchen or wash-house, were usally under the control of one of the rougher out-door servants, and from these the first commercial brewers must have obtained the earliest rudiments of their practice. How far back brewing was conducted upon a really extensive scale is a matter of less consequence to ascertain, inasmuch as until within the last sixty years brewing for private and domestic purposes produced by far the larger amount of the beer consumed. Whatever may have been the success attained by brewing

for a general sale, it is certain that the quality of the beer brewed, as compared with its price, was not such as to tempt those who rejoiced in their home-brews to save themselves the trouble and care which must necessarily have been bestowed to produce anything drinkable. Even in London, private brewing continued, notwithstanding the successful efforts of the Thrales and others, afterwards assisted by the financial co-operation of some of the richest of the mercantile community; and within the last fifty years many a bushel of malt has been mashed in tubs very similar to those of the laundry, within a stone's throw of some of the largest breweries.

It would be curious, if we were able, to compare the results of these small hap-hazard operations, conducted under every possible disadvantage, with the beers brewed by means of the best skill then attainable. One thing, however, is certain, and that is that the producers of the home-brewed ales never believed in the superiority of any beverage they could purchase; and if the beer obtainable from large breweries was not superior to the home-brewed ales of the present day, it is equally certain that public brewing must have made vast strides in the improvement of quality, especially in the lighter ales.

In these early days, strong, heavy, rich ales were believed in both by the public and private brewer, for they afforded the greatest then known security against acidity; and, possessing great keeping qualities, plenty of time was allowed for the beer to get into condition before it was put forward for sale or consumption. Darkness in colour was no objection, and in its different stages, from being heavy and saccharine to the development of the peculiar ethers, flavours, and sometimes acidity, to be found in "old ales," a far greater range of taste could be satisfied than is even now the case, with any other single class of beer.

The taste for these old vatted ales has been gradually disappearing for many years, until at the present time it only survives in a few remote districts, where the vast quantity of excessively acid cider still consumed accustoms the public palate to the excess of acidity usually found in the class of ales I am speaking of.

While these old ales have been going out of favour, the public taste has become from year to year more exacting as to the condition and flavour of the lighter and newer ales which have replaced them. The general good quality of the light ales now produced throughout the country, is a proof that the skill of the brewers has kept pace with the requirements of the public, and the enormously increased consumption is a great encouragement to them to make still greater efforts to insure a steady production of beers uniformly perfect, both as regards soundness, flavour, brilliancy, and condition.

Private brewing has lately received an artificial stimulus, owing to being specially favoured by the fiscal changes made in 1880, but although a few private brewers may succeed, under favourable circumstances, in producing drinkable beer, by far the larger quantity brewed must always be of most inferior quality, so that private brewing, if placed on an equal footing as regards fiscal charges with public brewing, would quickly and inevitably die out.

This is a matter that deserves and is receiving the attention of brewers, and no opportunity should be lost of pressing on the notice, both of the Government and of the public, the extreme unfairness of the present regulations, by which a few favoured individuals are enabled to escape their share of the burden of taxation, for no conceivable reason, except the caprice of a Government, which seemed always on the watch for opportunities of injuring the public brewer.

Something will be gained by an attempt to glance at the objects a brewer now has in view, after which we can proceed to the consideration of the means by which these may be most easily and certainly attained. From a general point of view, I take the chief objects of the modern brewer to be the production of a beverage that is wholesome and pleasing to the palate, nose, and eye, and such as will maintain these qualities for a sufficient period without deterioration. It is imagined by many that if beer is brewed from malt and hops alone it must necessarily be wholesome, but this is by no means the case. If either the malt and hops or the water are of bad quality, or if the process is carelessly conducted, a beer will be produced which cannot be considered as wholesome while new, and which will become rapidly more and more unwholesome on keeping. On the other hand wholesome and nutritious beer of first-class quality can be brewed from a mixture of malt with unmalted grain, and other saccharine producing substances, if the manipulations are conducted with the requisite care and skill.

To return to the characteristics of a good beer. Brilliancy of condition not only pleases the eye, but, when naturally induced, is one of the best evidences of successful brewing. The palate, following the impression of the appearance, requires, in addition, that the beer shall be well charged with carbonic acid, and retain it. In a negative sense the total absence of unpleasant flavours, especially those produced by bad yeast and want of cleanliness, is insisted upon by every refined taste, and is of itself of considerable dietetic importance. A pretty general consensus of opinion demands a sufficiency of body without excessive sweetness, and the fine aroma of the hop with its pleasant genial bitter, which should immediately leave the palate clean, without any excess of harsh or otherwise unpleasant bitter.

Such are the general characteristics of good beers, and they will be found, modified within certain limits, to be essential to the successful brewing of the most opposite descriptions of malt liquors. A due balance of fulness and alcoholicity, of saccharine and bitter flavour, is as indispensable in the lightest pale ales as in the strongest beers, whether mild or bitter. The same is equally true of the heaviest stouts and lightest porters. However various the tastes of the upper and lower classes, as manifested in their selection of beers in different localities, the malt liquors in which such characteristics are found developed in their highest perfection are those which have stood the test of the longest experience, and made for themselves the most enduring reputation, so as to enhance the demand for beers of their own peculiar type.

The annals of brewing have conclusively shown that the uniform production of the best beers, whether cheap or expensive has always afforded the most gratifying commercial results. We have now to consider the most appropriate means of ensuring, not only the best results, but also the maintenance of the nearest possible approach to uniform quality; for, be it well understood, nothing can be more detrimental to the interests of any brewery than the occasional sending out of beer of superlative excellence, as contrasted with a general average of a mediocre character, varied by a not unfrequent delivery of decidedly bad beer.

The subject-matter will be, perhaps, best divided under three heads. The first comprises the plant, the proper arrangement of which is of even greater importance than the mere elaboration of details. Beers of the very highest class can undoubtedly be brewed with an adequate plant of the simplest construction, if the arrangements are sufficiently perfect. On the other hand, the most costly, ingenious, and complex machinery and apparatus will not ensure the

possibility of the production of a reliable and always saleable beer. So far is this from being the case, that I regard simplicity of arrangement as being the most important safeguard against many of the evils incident to brewing, while I have been frequently enabled to trace supposed inherent defects to undue complications of arrangement of plant. At the same time, the real merit of modern improvements in the plant and machinery must be fully recognised, and will be duly considered, not only with regard to their bearing upon the improved production of beer, but also as effecting true economy.

The materials used in brewing will be dealt with as comprehensively as possible under the second head, and the third section will be devoted to the description and critical examination of the actual process of brewing.

In the introduction to my original treatise on brewing I promised my readers to give in conclusion a *résumé* of the general subject from a more scientific point of view, so as to explain the relation between the most advanced theories, and their practical application, in such a form as to render them available to those who wish to assume the foremost position in the applied science of brewing. This promise was I fear very inadequately fulfilled, other engagements having prevented me from giving the time to the work which was necessary for the due elaboration of the subject.

In the present edition I have determined to pursue a different plan, and to divide my subject into two distinct parts, each complete in itself.

The first part will include the three heads of Plant, Materials, and Process, and in it I shall endeavour to give as fully as possible all the information which it is absolutely necessary for the practical brewers of the present day to acquire. In fact, this part will treat of Practical Brewing, or in other words it will be Brewing Practically Considered.

In this first part I shall only touch on the more theoretical and scientific subjects connected with brewing, in so far as a knowledge of them is indispensable to the intelligent working of the brewery.

Later on I hope, in my second part, to really fulfil the promise quoted above, from the introduction to my first edition. In it I propose to borrow freely from recent researches on starch and its transformations, on fermentation and the organisms which produce and accompany it, and to endeavour to trace the relation between the scientific facts and the practical results, as we find them in the brewery.

In this second part I hope also to give a series of original photomicrographs and also some remarks on the use of the microscope in the brewery; and in fact to make it as fully as possible correspond with its title of Scientific Brewing, or Brewing Scientifically Considered.

If this my first part is favourably received by the brewing world in spite of its numerous imperfections and shortcomings, I shall feel encouraged to devote my time to the somewhat arduous task I have set myself, and to endeavour to complete my second part as early as possible, trusting that the same kind indulgence will be extended to it also.

I trust that all the kind friends who have assisted me in completing this first portion of my work, will accept my most sincere thanks for their co-operation, and I must especially acknowledge my debt of gratitude to Mr. Walter Ramsden for his invaluable assistance in revising the engineering portion of my subject; to Mr. Charles H. Jolliffe for the able manner in which he has helped me with the chapters on the materials and process; and to Mr. Palm for kindly revising my description of the decoction system of mashing.

CHAPTER I.

GENERAL ARRANGEMENT OF THE PLANT.

NO one who has inspected large numbers of the breweries of this country can fail to have been struck with the extraordinary diversity of the arrangement of the plant, and the want of any general agreement amongst those who have erected the breweries as to the objects to be attained, or the best method of attaining them.

No doubt, in many of the older breweries, and especially in those which have grown gradually from small beginnings into large concerns, there is no pretence of anything like a scientific arrangement of the plant, and, indeed, in many cases this could scarcely be expected. But it is most extraordinary how seldom a really well-arranged brewery has been erected, even when no expense has been spared, when there has been ample space at command, and when experienced architects and engineers have been employed.

In arranging the plant and construction of a brewery many local considerations, such as the space available in proportion to the size of plant required, and the utilisation of old buildings, &c., have frequently to be taken into account. These vary in every instance, and

must be met as they arise; but supposing an entirely new brewery has to be erected, there are two main systems of construction, either one of which may be adopted, or some modification intermediate between these two systems may be preferred. Special advantages and disadvantages appertain to each of the above systems, and to all their modifications, and these I will now proceed to consider. The two systems are, first, what is generally known as the Tower system, and, secondly, what I propose calling the Horizontal system.

On the Tower system, when fully carried out, the water is pumped direct from its source into the cold and hot liquor backs at the top of the building, which is of a sufficient height to obviate the necessity for any further pumping of either wort or beer. On this system therefore, the water flows to the mashing machines and mash tuns, the wort from the latter to the underback and coppers, the boiled wort to the hopback, and thence successively to the coolers, refrigerators, fermenting tuns, cleansing casks, and settling backs and thence into the trade casks.

The advantages of this system were so obvious that when first introduced it was eagerly adopted by a large number of brewers, and it is still very generally advocated by those who have had no practical experience of its defects.

The great and manifest advantages of the Tower system are, the much shorter length of pipe required for conveying the wort and beer from one portion of the plant to another, and the entire suppression of the wort and beer pumps. As dirty pipes and pumps are probably the cause of half troubles in a brewery, the suppression of the latter and reduction in length of the

former, are advantages which every brewer will at once acknowledge. What then, are the disadvantages which have prevented the universal adoption of the Tower system, and have caused it to be disliked by most of those who have had much experience of Tower breweries? The disadvantage which is immediately apparent to the brewer from the first day he takes the general supervision of a Tower brewery, is the enormous number of stairs, and the physical impossibility of ascending and descending them more than a certain limited number of times daily. It is all very well first thing in the morning, for the mash tun is in a snug little room, and the hot liquor back in convenient proximity to it; but later on in the day his attention is required in three or four different departments within a few minutes, and then he realises the absolute impossibility of seeing that the sparging and running off of the worts is being properly attended to, the tunroom men doing their duty, and that at the same time the racking and loading up is not being neglected.

But besides the difficulties of supervision, it is a serious objection to this system that the cost of any alterations of or additions to the plant is greatly increased, and also restricted within very narrow limits. A Tower of even small dimensions is a costly structure, and everyone is therefore inclined, to restrict its size and consequent cost as much as possible. When once the Tower is erected it cannot be enlarged except at an enormous expense, if therefore the trade extends so as to exceed its capacity, it is for all practical purposes a new brewery that has to be erected.

I have dwelt thus fully on the demerits of the Tower system, because at first sight it is so captivating. I will

next consider what are the chief advantages and disadvantages of what I call the Horizontal system.

The brewery in this case consists of a long building of two or more stories, or of several such buildings placed side by side. The wort has to be pumped twice; first from the underback to the coppers, and a second time from the hopback to the coolers. The latter must be placed at such a height as will command the refrigerators, and the refrigerators the fermenting tuns; and if the system is adopted of cleansing into unions, the half-fermented beer must also be pumped to them.

I think the best arrangement, and one which should always be adopted where a suitable piece of land can be obtained, is as follows:—

Two buildings are erected side by side, the height of the main walls of which need not exceed 25 feet for a plant of 40 or 50 quarters; the width of each building being about 30 feet. I will call these two buildings No. 1 and No. 2.

In No. 1 there is first the pump room, with hop stores above; secondly, the mash tun room, with underback below, and with the grist cases, converter, and hot liquor back, above the mash tuns; thirdly, the engine room and mill room below, with malt stores above; and, lastly, the fermenting tun room, with racking room below. If cleansing into unions is adopted, the union room forms an extension of the fermenting tun room, a centrifugal pump raising the beer from the tuns, to the unions, which are all on the same level.

In No. 2 building I place the hop back first, in a line with the pump room in No. 1. Then come the coppers, stoking hearth, and steam boilers, and lastly, the cask

washing and cooperage departments, which thus run parallel with the racking room in No. 1.

In No. 2 building, above the steam boilers, I place the coolers or wort settling back at a high enough elevation to command the refrigerators, which latter command the fermenting tuns in No. 1 building.

The two cold liquor backs form a portion of the roof, but are themselves covered with a light roof of galvanised iron.

Above a portion of the cask washing shed is a large hot liquor back at a sufficient elevation to command the fermenting tuns. The hot liquor from this back is used for washing the tuns, casks, &c., &c., and the water from the refrigerators and attemperators is utilised, as far as possible, for the supply of this back.

In the fermenting room I erect a cold liquor back to supply the attemperators only, and both the brewing hot liquor back, and this attemperating cold liquor back, I supply direct from the rising main of the water pumps.

The immense advantages, as regards convenience of working, possessed by this Horizontal system are manifest, for the brewer has everything under his eye, and every portion of the brewery is accessible to him on the easiest terms.

From the mash tun room as his centre of operations, he can step direct on to the copper stage, and a short passage partitioned off from the malt store conducts him into the fermenting rooms, with the racking room below.

Another advantage of this system of construction is, that by excavating the space under the two buildings, larger and better cellarage is secured than it is possible to obtain below breweries built on other systems.

The question is, what are the disadvantages of this system? Well, I think they may be summed up as consisting in the necessity for having two or at most three additional pumps, and a considerable extra length of wort and beer mains. Now, if it was impossible to keep these pumps and mains clean, I should say at once that these objections were fatal; but the fact is nothing is easier than to keep pumps and mains clean, provided they are properly erected. All that is necessary is, that every time they are used they should throughout their whole length be rinsed with clean hot water, and steam then blown through them. Of course, proper steam and water connections and outlets must be fitted to the mains, which must be so arranged that the water and steam will pass through every inch of them; but if this is done, one man or even a boy can effectually wash and steam every main in a large brewery in the course of an hour or two at the outside.

Rotary, or centrifugal pumps should in all cases be used for wort and beer, and these pumps should be placed below the level of the liquid to be pumped. Rotary and centrifugal pumps are now made of such an excellent construction, that no brewer who has once tried them will go back to the old three-throw pumps, at any rate, for wort and beer. In fact, the three-throw pumps should only be used where the level of the liquid to be pumped is below that at which the pump can be conveniently placed, as in the case of water from wells, borings, &c.

The only system intermediate between the Tower and Horizontal constructions, that calls for any special notice, is that in which the mash tuns and underback command the coppers, and the boiled wort is pumped

from the hopback on to coolers, which are placed at such an elevation as to command the fermenting tuns, which again command the unions, and the unions the racking squares. Only one pumping of the wort is necessary on this system, and that the boiled wort. The necessary elevation of the buildings is somewhat considerable, but not nearly so excessive as on the Tower system. The mains are very simple, and the whole available space in the buildings easily utilised.

I need not dwell on the details of this form of construction, as they will be evident at once to every brewer. The most notable instance is Messrs. Allsopp and Sons' splendid brewery, adjoining the Railway Station at Burton-on-Trent. The old brewery in the High Street belonging to the same firm is on the Horizontal construction, as are most of the other breweries in that well-known centre of the brewing trade.

CHAPTER II.

WELLS AND WELL SINKING, AND WATER FILTRATION.

WHEN a well is about to be sunk, the first thing to be determined is the strata through which it will have to be carried. Valuable general information can generally be obtained from the geological maps of the district, and further particulars can often be gleaned by enquiries as to the strata passed through in sinking other wells and borings in the neighbourhood ; but it is nearly always advisable to sink a trial boring of two or three inches diameter, so as to obtain more exact information, and also to ascertain with certainty whether a sufficient supply of water can be obtained, at what depth it is reached, and what are its chemical constituents.

It seems so self evident that in choosing the site for a brewery, the possibility of obtaining a good and abundant supply of water ought to be the very first consideration, that it may almost appear impertinent to insist upon this point, but I have so often come across instances in which heavy loss has been incurred by the neglect of this precaution, that I must dwell upon its absolute necessity.

The presence of an abundant supply of water having been ascertained, and its quality proved to be satisfactory by careful chemical analysis, the third point to decide upon is how to secure the supply in its full abundance and purity. I will therefore next consider the various methods by which this may be accomplished.

The well-known Abyssinian tubes are probably the best and simplest means of obtaining a supply of pure water, where this exists at a moderate depth; but, unfortunately, their application is somewhat limited.

In the first place, the depth to which one of these tubes can be driven, even under favourable circumstances, rarely exceeds fifty feet. And, in the second place, these tubes can only be driven in moderately soft strata, and those that are free from boulders or other large masses of rock.

The method of driving tubes is so well known that it needs no description here.

When circumstances will not allow the use of the Abyssinian tube, an ordinary boring, a dug well, or both combined, must be resorted to.

In all cases in which the water-bearing strata are at a considerable depth, and the water rises to within about twenty feet of the surface, with sufficient rapidity to supply the maximum amount required, the simple boring is the best and cheapest arrangement. If a good and permanent job is required, the boring must be lined with heavy wrought iron lap-welded tubes, of about half an inch in thickness, screwed firmly together. The external portion of the end of these tubes with the male screw on it, is cut away to half its thickness, and also the internal half of the end with the female screw; so that when the tubes are screwed together, the cor-

responding male and female screws being of exactly the same length, the remaining thickness of the ends butts against the solid tube, and the whole forms a pipe uniformly smooth inside and out, and that can be driven as securely as if it had no joints whatever.

All other varieties of tube are quite untrustworthy, being liable to split, or the screws to strip, when any force has to be used in driving them; and unless the bore tube is driven very tight through the boring, there is no security that impure surface water will not find its way down along the outside of the tube, and contaminate the deep spring. The reason why so many tube wells yield an impure water, is either that the tubes, being of bad make or too thin, have split during the driving, or because the tube has not been driven tight enough into the bore hole, or, lastly, because the tube has not been carried far enough down the boring. As a rule the boring should be tubed throughout its whole length, until good solid rock is reached, and the tube should be driven for some feet into the rock. Chalk does not generally require tubing, but neither marls nor clays, however hard and firm, are safe unless lined.

When the water does not rise near enough to the surface, or when it does not come up in sufficient quantity, and a reservoir must therefore be formed, a dug well in addition to the boring becomes necessary. These wells must be lined so as to exclude the surface water; and the best and cheapest lining consists of cast-iron cylinders, well jointed by means of internal flanges bolted together, with a good layer of hemp gasket soaked in hot tallow between them, and the head of each bolt surrounded with a grummet of the same material.

These cylinders are driven down as the excavation

proceeds, the lower end of the bottom cylinder being formed with a cutting edge in order to facilitate this operation.

This cutting edge is finally driven into the impervious stratum, which should in all cases form the bottom of the well. When the well is completed, and before the boring is commenced, the former must be proved to be absolutely water-tight, which is easily ascertained by seeing that no water collects in the well after it has remained untouched for say twenty-four hours. The boring is then commenced and carried down to the necessary depth.

Ordinary dug shallow wells have still to be sometimes resorted to, although the Abyssinian tubes should be substituted for them whenever the local conditions will allow.

In the chalk formation, and also in rock, dug wells can be constructed very cheaply, as no steining is required after the solid chalk or rock is reached. In such wells the superficial strata should be removed down to the solid rock or chalk, and to a diameter three feet larger than the finished well. Then from the solid chalk or rock up to the surface, nine inch brickwork should be carried, and nine inches of clay well puddled in at the back of the bricks as the work proceeds, so as to perfectly exclude all surface water. The top eighteen inches or two feet of the brickwork should be laid in cement.

When the well has to pass through stratifications of too friable a nature to admit of the above method, the drum or sinking curb becomes indispensable. The simplest and cheapest form, but by no means an efficient one, is the wooden drum curb, which is a stout cylinder

of wood, supported internally by wooden curbs, to which the planking is strongly nailed ; the lower edge is fastened firmly to a stout iron hoop ; this drum is loaded with dry brickwork, built up so as to form the sides of the well, and is sunk as the excavation proceeds, care being taken by means of plummets to keep it vertical. There are great objections to this curb, both from the wood decaying after a time and contaminating the water, and still more from the impossibility of keeping out the impure surface or other waters from a well so constructed.

Formerly the solid brick and cement sinking curb was used to obviate the above faults, but the cast iron cylinders already described, are now exclusively employed, and are certainly the cheapest and best form ot sinking curb. A well formed of such cylinders, can be rendered perfectly safe from all surface infiltration, if proper precautions are observed. The iron cylinders are not usually carried up to the surface of the ground, but only to a short distance above the surface springs, the upper portion of the well being completed with brickwork laid in cement, or puddled with clay.

I have been somewhat particular in describing the various methods of well sinking, as this is a matter too often left entirely to the discretion of the local well sinker. It is comparativelyeasy, in the first instance, to adopt such means as will ensure a good tight well, but very difficult to correct any fault of original construction.

When from any cause there is, unfortunately, an infiltration of surface or other objectional water, or when the brewing water is derived from rivers or reservoirs, filtration is essential. If the water is supplied by public companies carrying out an efficient system of filtration,

the filters of the brewery need only be provided for the emergency of occasional imperfection in the company's arrangements. But when the comparatively impure water comes unfiltered to the brewery, nothing less than the most perfect system of filtration will render it safe to use for brewing purposes.

Experience has now proved that the water supply of even the largest breweries, can be perfectly freed from recent organic impurities, by Rawling's Patent Animal Charcoal Filters, and when the water is free from machanical impurities these filters are alone required. When, however, the water is not only impure but muddy, sand or coke filters of sufficient capacity must be employed to remove all solid matters, which would otherwise choke the pores of the char, and render it inactive.

Some filters are advertised as remaining active for long or even unlimited periods without any change of the filtering medium. All such assertions must be regarded with incredulity, for it has been practically proved that all filtering media lose their efficacy in a comparatively short space of time.

Animal charcoal, specially prepared by careful washing and reburning, is the best and most efficacious of all filtering media, and experience with it in the filters I have named above, and in which its powers are fully utilised, proves that it will retain those powers for periods varying from two to six months, according to the amount of impurity in the water. In most cases a fresh charge of char is required either three or four times a year when the filters are in daily operation. The largest filters yet erected on this system are capable of purifying from 150 to 200 barrels per hour.

CHAPTER III.

PUMPS AND MAINS.

IN the ordinary process of brewing the first operation is to raise the water from its source to the vessel in which it is to be heated ready for mashing. I shall therefore commence my consideration of the brewing plant by alluding to some of the principal varieties of pumps, and more especially to those which I consider best adapted for brewing purposes.

The following is a list of the most important forms of pump at present in use :—

- The lift pump.
- The lift and force pump.
- The three-throw lift and force pump.
- The double action pump.
- Donkey pumps with fly wheels.
- Donkey pumps without fly wheels.
- The rotary pump.
- The centrifugal pump.
- The chain pump.
- The pulsometer.
- The various forms of water elevators on the injector principle.

The simple lift pump is too well known to require any special description. Its simplicity and cheapness recommend it for house and farm purposes, where the water is obtained from shallow wells, but it is not adapted for breweries, except perhaps those of the very smallest size. There is, however, a variety of this pump commonly used in mining districts for raising the water from the bottom of the shafts. In this form the barrel is placed within easy reach of the water, and lengths of pipe are jointed on to the top of the pump barrel upwards, until they reach the level at which the water is to be delivered. The piston rod passes up through the whole length of these pipes, and is raised and lowered by a crank with a heavy counterpoise, so as to balance the great weight of the pump rods, and equalize the action as far as possible. This is a simple but very clumsy arrangement, a modification of which may, however, be usefully employed when it is necessary to raise water from near the bottom of a large boring, in which it does not rise to near the surface, and where there are difficulties in sinking a well to within reach of the water.

The single-barrelled lift and force pump is as well known and needs as little description as the lift pump; almost every house above the size of a day labourer's cottage, and not supplied by a water company, depends on this pump for its water supply. It is an excellent hand pump, but owing to its throw being intermittent, it is not adapted for driving by power.

The three-barrelled lift and force pump, commonly known as the three throw pump, overcomes the above objection to the single-barrelled lift and force pump, and is more commonly used for all purposes in the

breweries of this country than any other pump. The three barrels working alternately, especially when assisted by an air vessel on the rising main, secure a fairly equable flow through the latter, and this pump is equally adapted for working at the bottom of a deep well, or for raising liquids within the brewery. The objections to this form of pump are twofold, for in the first place, as it has to be driven from a shaft, the main brewery engine has to be kept at work the whole time it is in operation; and secondly, owing to its system of valves it cannot be so thoroughly cleansed by steaming, as the valveless rotary and centrifugal pumps, and it is not, therefore, so well adapted in that respect for pumping wort and beer.

Donkey pumps, in which steam driving cylinders are combined with the pumps, are free from the first objection I have mentioned above. They only require connecting with the steam boiler by means of a wrought iron pipe of one or two inches in diameter, and can be started at any moment without interfering with the large engine or other machinery.

These donkey pumps are of two principal descriptions, viz., those with fly-wheels and those without. The latter are perhaps theoretically the most perfect instruments, but for practical purposes in the brewery I greatly prefer the fly-wheel pumps.

I have used large numbers of these fly wheel donkey pumps, by good makers, and they have never given me any trouble. They will stand the rough usuage to which they are liable in the hands of careless and unskilled labourers, and if at any time through excess of illusage, any part of them is broken, it can be quickly and cheaply replaced, for each part is made to a fixed

pattern, which can be purchased separately, and fitted, so as to replace the broken part by the brewery workman without calling in skilled assistance.

There are several makers who turn out excellent donkey pumps, but this is not universally the case, and I must warn brewers only to purchase from firms they can depend upon, for bad donkey pumps are dear at any price, being a constant source of loss, annoyance, and expense. I speak feelingly, and from long experience on this matter.

In choosing a donkey pump it must always be borne in mind, that it requires an air vessel both on the suction and rising mains, and one frequent cause of the imperfect working of these pumps is the omission of one or both of these air vessels.

The donkey pumps, without fly-wheels, and by the best makers, are really beautiful pieces of mechanism, but unless the brewer keeps a skilled mechanic on the premises, he had better have nothing to do with them. I am alluding here more especially to the smaller sizes of these pumps; I believe the large sizes, by the best makers, are more satisfactory from a practical point of view.

The best forms of rotary pump are most useful and convenient, and have been too long neglected by brewers. I cannot recommend the single spindle forms but those with two spindles, and especially those known as double cog-wheel pumps, are excellent. In fact, for pumping wort and beer, I consider these pumps superior to all others. They work equally well at either a slow or fast speed, they occupy very little space, and if well made, are very durable, and not liable to get out of order.

The most important advantage, however, of these rotary pumps for wort and beer, is that having no valves they can be steamed as easily and perfectly as the pipes themselves, and as there are no inside cavities, which are not passed over by the moving parts, they naturally tend to keep themselves clean, which is what certainly cannot be said of any other form of pump.

The original form consisted simply of two ordinary cog wheels, revolving in an elliptical box, so that the teeth geared together in the middle. These cog wheels revolved in contact externally with the semi-circular surface of the box, and with its flat sides through which the spindles were passed.

The newer forms have only either two or four teeth, so shaped as to produce as far as practicable a rolling motion of one tooth over the other one gearing into it, and the friction is thus greatly reduced. The inlet and outlet pipes are on the opposite flat portions of the elliptical sides.

The action of these pumps is very simple, and consists in the liquid which is forced up between the cogs on the outside, being prevented from returning by the cogs gearing into one another in the middle.

These rotary pumps will not suck for more than a short distance without a foot valve, especially with hot liquids. When used for pumping wort, either from the underback or hopback, the best plan is to fix the pump below the level of the wort, so that the latter flows into the pump, which, although weak in suction power, is capable of lifting to almost any height without requiring to be driven at any excessive speed. With cold liquids, such as beer, these pumps may be relied upon to suck about three feet of vertical height. When

fitted with a foot valve, their suction power is greatly increased.

Rotary pumps are not adapted for pumping liquids containing grit, as this soon cuts up the working faces. They are not, therefore, well adapted for pumping water from wells or springs, as traces of sand are always liable to come up with the water, their weak suction power also unfits them for this purpose.

Centrifugal pumps are too well known to require description. For some purposes they are simply invaluable, but their use is somewhat restricted, not only by their weak powers of suction in which they resemble the rotary pumps, but also by the very special mode in which they act.

In the case of all the other pumps that I have hitherto mentioned, the amount of liquid thrown is pretty nearly proportional to the speed at which the pump is driven, and even at a very low speed some liquid is raised to the required height. This, however, is not the case with centrifugal pumps; a certain speed is required for a certain height, and this speed rapidly increases with the height. If this necessary speed is not attained the flow of liquid thrown does not merely diminish but ceases altogether. The practical effect of this peculiarity is that these pumps are not adapted for raising liquids to great heights. But for raising thick liquids, to moderate heights, these pumps are better adapted than any other form.

Thus, in the Lager beer breweries, mashing on the German or decoction plan, the mash itself is rapidly and freely transferred from one vessel to another by means of one of these centrifugal pumps. In the same way in breweries using Pigeon or other converters, the contents

of those vessels may be transferred without risk or trouble from the converter to the mash tun, in cases in which it is found more convenient to place the former vessel at too low a level to command the latter.

Centrifugal pumps should also be used in all cases in which beer has to be pumped which is in a state of fermentation, and therefore containing an abundance of yeast cells. There is no practical risk of injuring the yeast and interfering with the fining of the beer when these pumps are used, for there are no surfaces in them working in contact with one another, and consequently liable to crush the yeast cells.

Centrifugal, like rotary pumps, can be kept perfectly clean by washing and steaming, and are therefore well adapted for use in breweries, and specially in those constructed on the Horizontal system, for on this system a good many pumps are required to pump both wort and beer, and it is essential that these pumps should be capable of being perfectly cleansed by simply rinsing and steaming them, while on the other hand they are not required to lift to any great height.

The other varieties of pump that I enumerated at the commencement of this chapter are not of much interest to brewers.

Chain pumps are sometimes used in small maltings, and in exposed situations, as they are not liable to injury from frost.

The Pulsometer, and also the injectors, are not adapted for breweries, as the steam used for the motive power is condensed in the liquid raised. This increases the temperature so that refrigerating water must not be raised by this means, and no brewer wishes to mix condensed steam with either his mashing water, wort, or beer.

The hydraulic ram is a most interesting and useful means of raising water, but unfortunately it only works well when on a small scale, and is better adapted for farm use than for breweries.

I will conclude this chapter with some suggestions as to the pumps best adapted for use in the various brewing operations.

For pumping water from depths of less than twenty-five or twenty-six feet, Three Throw Pumps and Donkey Pumps are the best forms.

For raising water from deep borings the Lift Pump, commonly used for pumping out mines, or some modification of it, can often be used with advantage.

For deep wells the Three Throw Pump stands pre-eminent as certainly the best adapted for the purpose; and I will here describe a special modification of this pump, which, for this purpose, possesses the great advantage that the bucket and valves are always accessible however high the water may rise above the pump barrels.

In this form the barrels of the pump are fixed at or near the bottom of the well, and each barrel is prolonged upwards by a stand pipe, which reaches to well above the highest point at which the water ever rises in the well. The top chamber of the pump is fixed on the top of the stand pipes so that by removing the covers the working bucket can be withdrawn. A hook can then be passed downwards until it engages the bale of the bottom bucket, which can then be raised by means of this same hook. All the working parts of this pump are therefore as accessible when it is at the bottom of a deep well, as those of an ordinary pump are when fixed at the surface.

When it is necessary to increase the suction on the spring, the suction mains of these deep well Three-Throw Pumps can be carried down the bore pipe to a depth of about thirty feet.

It is a common practice in breweries to use Three-Throw Pumps for raising wort and beer, but for these purposes rotary and centrifugal pumps are far better adapted, on account of the greater ease and certainty with which they can be kept clean.

For raising wort or beer to a height of more than twenty or thirty feet, the rotary pump should be used, but for lower lifts both the rotary and centrifugal are equally adapted. For pumping beer during fermentation the centrifugal is undoubtedly the best pump, and in this case a high lift can never be necessary.

For pumping thick mash, such as the contents of converters, the contrifugal pump is the only form available.

In many breweries it would be convenient to use automatic or Steel's mashers, but the low level at which the mashing water stands in relation to the mashing tun, renders this impossible. In such cases a good rotary or centrifugal pump may be used to give the stream of water sufficient force to allow of a Steel's or Automatic masher being used. In this way also in old breweries, where it is very advisable to increase the supply of mashing water, the new hot water back may be placed even at the ground level, in any spare corner, and the water raised by means of a rotary or centrifugal pump.

In erecting pumps it must be always borne in mind that the extreme height from the level of the liquid to be pumped up to the lower valve is for simple lift pumps, for lift and force pumps and for plunger pumps, 25 ft. For rotary pumps, with cold liquids and without a

foot valve, 3 ft. For rotary pumps, with hot liquids, and for centrifugal pumps, the liquid should always be on a level with or above the pump. With a foot valve these latter pumps have a certain amount of lifting power, but the foot valve is objectionable when the pumps are used for the purposes I have indicated.

In deciding on the number of pumps to be used in a brewery, there is one consideration which should never be lost sight of, and that is that the cold water pump must be used for nothing else but pumping water, and, if besides the pure water used for brewing, a more or less impure water is used for refrigerating and attemperating purposes, there should be two pumps, one for each class of water. With proper precautions one set of pumps may be used for both boiled and unboiled wort, but it is much more convenient, and far safer to have separate pumps, one for the raw wort, one for the boiled wort, and another, again, for the beer if that also requires pumping.

Mains for beer and wort should be always made of tinned copper pipe, with gun metal flanges and caps, and all T pieces should be formed of tinned sheet copper, with smooth surfaces and easy throats.

Water pipes may be made of cast or wrought iron, but lead pipes are not adapted for brewery use, and should be entirely excluded from breweries.

Thermometers should be inserted in the hot water mains supplying the mashing machines, mash tuns, and spargers. They should be placed in such positions as are most convenient to the brewer, and where at the same time the full flow of the water comes in contact with the bulb of the instrument. Fixed thermometers are also sometimes useful in the pipes from the spent taps.

CHAPTER IV.

COLD WATER TANKS AND MAINS.

THE tanks to hold the cold water to be used in a brewery may be made of a variety of materials, among which I may mention wood, copper, lead, zinc, wrought iron, galvanized wrought iron, and cast iron.

In a brewery the water is used for such a variety of purposes, that I cannot think the common practice of having only one tank to supply the whole is a commendable one, and now that tanks can be so easily obtained, and at such a moderate cost, there is the less reason for adopting it.

Every brewery should, in my opinion, have at least two cold water tanks, one for storing the brewing water, and a second for the water used for other purposes.

I much prefer having a third tank also in addition to the above, for the special purpose of containing the attemperating water.

In the case of those tanks which are to contain the water to be used in mashing and sparging, the essential requisite is that they should preserve it in the most perfect condition as regards purity ; the material of which they are composed must therefore be of such a nature that it is not acted on by the water. The surface

of the tank must be capable of being easily cleaned, and its shape must be such as to render it easily accessible, at the same time that every part can be seen at a glance, so that the brewer may assure himself that the cleaning has not been neglected. A light roof should be erected over the tank, especially in the case of breweries situated in large towns, and in the vicinity of chemical works, or where leaves or other refuse is liable to be blown into an uncovered tank. In every case care must be taken to exclude all drainage or drip from any contiguous roofs, to keep the water pure and unmixed as it comes from the well, and to place the tank in a light and easily accessible situation, where its condition can be ascertained at all times and without difficulty. As regards the materials of which the tank should be constructed, a wooden tank if properly made will answer well for a certain number of years, but sooner or later decay must commence, and then it becomes altogether unfitted for the above purpose.

Wood lined with copper makes a most unexceptional tank, but entails a large and unnecessary expense. Lead is so liable to be dissolved by water, that it can never be considered a fit material for lining tanks intended for storing water which is to be used for dietetic purposes. Zinc forms a very good lining for a tank if the sheets are heavy enough. Nothing less, however, than No. 14 gauge should be used, and it is advisable to make the bottom of even somewhat thicker sheet. In all these lined wooden tanks the wood should be well painted or tarred.

Wrought iron is so quickly acted on by water, especially when as in a tank, it is alternately wet and dry, that I do not consider it a suitable material for

containing brewing water. The scales of rust which form on the surface of the wrought iron are non-adherent, and as the corosion proceeds these scales peal off, leaving an uneven surface, which it is difficult to keep clean.

Ordinary paint, mixed with linseed oil and turpentine, affords but an imperfect protection against oxidation. Some spirit varnishes have much greater protective power when applied to wrought iron than ordinary paint possesses ; but these spirit varnishes, to be really effective, require the aid of a somewhat high temperature to render them permanently adherent, and their application is, therefore, troublesome.

Small iron tanks, galvanized after they are put together, are useful for many purposes, but cannot be made of the size required to contain the brewing water, for any but the smallest breweries.

Cast iron is, perhaps, the only material that can be used for the construction of the tanks that are to contain the brewing water, which is at the same time cleanly, indestructible, and of moderate first cost. Cast iron is naturally coated with a layer of carbide and silicate of iron, which has a remarkable power of resisting oxidation. If this outer skin is removed, the liability to oxidation is considerably increased, but under similar circumstances cast iron will never oxidise with the same rapidity as wrought iron. Even when an oxidised coating forms on cast iron, it adheres with considerable tenacity, so that under all circumstances cast iron possesses great advantages over wrought iron in this respect. Cast iron tanks being composed of a number of panels bolted together, it is necessary to provide very rigid supports to carry them, and the supports must be

equally unyielding on all sides, or the tank will not remain water tight. Solid walls and iron girders, with brick, stone, or iron pillars, are the only proper means of supporting these heavy tanks.

The panels of cast iron water tanks are held together by means of bolts passing through the flanges, which are cast on the four sides of each panel. There are several ways in which the joints are rendered water tight. The old plan was to keep the flanges a short distance apart, by chipping strips or fillets round the inside edges, and then to fill the spaces thus left between the flanges with iron cement well caulked in; this plan makes good tight work, but it exposes a certain amount of rough uneven surface of oxide of iron to the action of the water. A great improvement on the above plan has been introduced of late years by which this objection is entirely got rid of—the flanges of the plates being planed with perfect accuracy, so that they only require a coat of paint, or a piece of very thin india-rubber sheet, interposed between them in order to render the joints perfectly tight as soon as they are firmly bolted together. All brewers' utensils made of cast iron should be jointed in this way, and most excellent tanks of every size and shape can be obtained of this construction.

The outsides of cast iron cold water tanks should always be well painted, and the first coat should be of boiled oil, with a little red oxide of iron paint or ochre added to it to give it some body. The insides of these tanks had better be left unpainted, and only covered with an occasional wash of lime. All metal tanks containing cold water, when exposed to steam, as they generally are in a brewery, have the unpleasant peculiarity of dripping condensed water on everything

below them ; it is well worth while to obviate the unpleasant effect of this perpetual dripping by erecting under such tanks a light roof of galvanized corrugated iron, with gutters to carry off the condensed water.

In the case of those tanks which are to contain the refrigerating and attemperating water, the most important consideration is that the water shall be kept as cool as possible. This is a point that I do not think has received, in most breweries, the attention it deserves; two or three degrees of heat will often make all the difference in the possibility or otherwise of refrigerating and attemperating the beer to the temperature desired, and if a naked metal tank is placed where the steam from the brewery can condense on it, the water will quickly gain several degrees of heat. For this reason, wherever from the nature of the supply of water it is not practicable to pump it direct from the well through the refrigerator, which is by far the best plan, it is advisable to have a separate tank for holding the water that is to be used for cooling purposes. This tank should be removed as far as possible from the heat of the brewery, and it is best made of the shape that exposes the least surface in proportion to its capacity. If from any circumstance it has to be placed where it can be effected by the heat of the brewery, it should be covered over, and either made of a slow conducting material or coated with felt.

Wood, as a slow conductor of heat, is a very suitable material, the drawback to its use being its perishable nature.

Wood lined with metal is much better in this respect, and with felt between the metal and the wood the non-conduction of heat is rendered as perfect as possible.

For the smaller sizes of cold water tanks, wrought iron, galvanised after the tank is put together, is a very suitable material, and if such tanks are clothed with felt they will keep the water as cold as possible, while at the same time they are cheap and durable.

In some breweries the supply of water for the attemperators may be conveniently obtained from the tank in which the refrigerating water is stored; but it is generally better to erect a special tank for the supply of the attemperators only. This tank should be placed in some part of the fermenting rooms, and the necessary precautions, as detailed above, taken to keep the water as cold as possible.

When this special tank for the attemperating water is dispensed with, means should be taken to equalise and moderate the pressure from the main tank, and this object can be most conveniently accomplished by placing a small supplementary tank, only holding a few gallons, and supplied by means of a ball cock, between the main tank and the attemperators.

The adoption of these two precautions, viz., the keeping the water supply to the attemperators as cold as possible, and at a perfectly even pressure, are of the greatest importance, and I have known cases in which their neglect has been the principal cause why brewers have failed in producing ales of uniformly good quality during the warm months.

Having now described the general principles which should govern the distribution and storage of water in a brewery, I will illustrate the subject by describing a special arrangement applicable to a brewery provided with two water supplies, one pure and the other of inferior quality, and with three cold water tanks.

At the close of the last chapter I insisted on the necessity of having two water pumps, one for each of the above qualities of water. In the following description I shall call the pure water pump and the mains connected with it No. 1, and the pump for the impure water with its mains No. 2.

The rising mains of both these pumps are carried up to a sufficient height to command all the cold, and also the hot water tanks, backs. or coppers. The branches given off from these rising mains are as follows.

First, both No. 1 and No. 2 give off branches to the cold water tank placed in the fermenting room for the supply of the attemperating water. Both these branches when they reach the tank terminate in ball valves, that on No. 1 main being fixed so as to close before that on No. 2 main; so that No. 1 water is only used for attemperating when the supply of No. 2 water is deficient.

No. 1 main next gives off a branch to the hot liquor backs, or coppers; which branch is furnished with the cocks or sluices necessary to regulate the supply for each of the above vessels.

Above this No. 1 main gives off a branch of its full diameter for the supply of the pure water store tank. This branch terminates in a ball valve large enough to allow, when open, the whole of the water thrown by No. 1 pump to pass through it.

No. 1 main is then carried upwards to a height of at least five or six feet above the level of the last-named tank, and then terminates in an open end, commanding the main store tank for the No. 2 or impure water.

No. 2 main, after giving off the branch already mentioned to the attemperating tank, gives off a second branch, furnished with a sluice or stop cock and of large

size, to the refrigerators, and above that branch terminates in an open end commanding the store tank for No. 2 water.

The effect of the above arrangements is that the attemperating tank is always kept full of water direct from one or other source of supply. The water for mashing and sparging is also pumped as far as possible direct into the vessels used for heating it. As much as is required to keep the store tank for No. 1 water full runs to it, and the balance flows into the store tank for No. 2 water. The No. 2 water also can be pumped direct through the refrigerators, and what is not used flows forward into the No. 2 store tank.

The above arrangements are all automatic, and no waste of water can occur unless No. 2 store tank is allowed to overflow.

The other cold water mains and connections required in a brewery arranged as above are as follows :—

From the attemperating tank, pipes and connections of ample size to all of the attemperators.

From No. 1 tank, a main giving off branches furnished each with a sluice or stop-cock to supply each of the hot water backs or coppers, and also the attemperating tank, so that a supply of water may be obtained for attemperating from No. 1 tank if all other sources of supply fail.

From No. 2 tank one branch is carried to the refrigerators in order to supply them with water when the pumps are not in operation. A second main from this tank descends to the lowest floor of the brewery and cellars, giving off branches to the attemperating tank, to the Hot washing water tank, and also a branch of large size on each floor. All these branches must be furnished

with sluices or stop-cocks, and on each floor a hose should be suspended in a convenient position, and furnished at one end with a union, by means of which it can be quickly connected with the cold water supply sluice or stop-cock, belonging to the room in which the hose is suspended.

This latter arrangement is not only very convenient for washing down, filling vessels not in use with water, &c., but it constitutes an invaluable protection in case of fire.

Branches should also be provided to conduct the waste water from the attemperators and refrigerators to the Hot washing water tank, so that it may be utilised there as far as possible. These branches must be provided with sluices so that the water can be shut off from the above tank, and when these sluices are closed a T piece with an open branch rising above the level of the tank, allows the water to flow away to waste.

CHAPTER V.

HOT WATER BACKS, COPPERS AND MAINS.

HOT water is used in a brewery both for brewing, properly so called, that is to say, for mashing and sparging, and also for washing purposes. When the hot water is required for washing only it is of very little consequence how it is heated, provided that this is accomplished in the most economical manner and with sufficient rapidity. In discussing the various methods of heating water, I shall therefore devote most space to the consideration of those which are specially applicable to the preparation of the water required for mashing and sparging.

The modes of heating water for use in the brewery may be classed under the following heads, and I shall consider them in the order in which they are enumerated :—

1st. The water may be heated in the ordinary brewing copper by means of a fire placed underneath the copper.

2nd. It may be heated by means of steam driven directly into it.

3rd. A detached boiler may be used, which is heated by a fire, and connected with a tank containing the water by means of circulating pipes arranged for the flow and return of the latter, as in the hot water apparatus ordinarily used for heating buildings.

4th. The exhaust steam from a non-condensing engine may be utilised by means of certain special arrangements which have been lately introduced for this purpose, and which utilise the steam without causing any back pressure on the engine, or allowing the condensed water to mix with that which is being heated.

5th. The water may be heated by means of steam circulating in pipes formed into coils and zigzags, or the same object may be accomplished by means of steam jackets.

Of the above systems the ordinary fire heated copper offers few points which call for special remark. In old-fashioned breweries the same copper is used both for heating the water and boiling the worts. The most serious objection to this plan is its inconvenience.

There seems a prevalent notion in Burton that the water ought to be heated in large domed coppers, and to this there can be no objection except the excessive first cost of the apparatus; but, on the other hand, there would seem to be no distinct benefit to be derived from this plan.

The second method, viz., that of driving steam directly into the water to be heated, has so many objections when applied to heating the brewing water, that I should never recommend it to be used for that purpose. The economy and simplicity of the plan, however, are strong points in its favour, and there are few, if any, better methods of heating the washing water.

The principal objections to heating the brewing water by means of free steam are as follows: In the first place, waters which naturally contain the salts so desirable for brewing purposes are diluted by the condensation of the steam, instead of being more or less concentrated as they are on other plans of heating.

Then again, it is almost impossible to ensure the purity of the water in the steam boilers, and some of this water is certain to occasionally flush over with the steam, especially when it is first turned on.

The very high temperature also to which the water is subjected in the steam boiler, owing to the pressure maintained in the latter, sometimes causes decomposition of any organic matters contained in the water, thus producing noxious vapours.

Another and very common objection to the use of free steam for heating water, even when the latter is to be used for washing purposes only, arises from the noise caused by simply injecting steam into cold water. This objection may, however, be obviated by inserting a few feet of the open end of the steam pipe into another pipe of about double its diameter, which second and larger pipe must also extend for some distance beyond the orifice of the steam pipe. Provided this arrangement is properly carried out, the noise will be so much reduced as no longer to afford any just cause of objection.

The third method, in which the water is heated in a detached boiler connected with the hot water tank by means of circulating pipes, has been strongly recommended by many engineers, and with certain waters it would seem to be a most convenient and economical plan, its only objectionable feature being the furring up of the boiler. This, however, is not of much consequence when the water is naturally soft, and when it is not intended to artificially harden it. The same may be said even in the case of hard waters, when the hardness is entirely due to the presence of salts of lime and magnesia, other than their carbonates, for the hardness is then of a permanent character, no precipitate being

formed by boiling, while, on the other hand, it is not necessary to boil the brewing water long enough to cause the lime salts to crystallize out and form a scale in that way. When, however, carbonate of lime is present to any considerable extent in the water, which is nearly always the case in good brewing waters, or when the water has to be hardened artificially, the consequent furring of the boiler renders constant chipping of its internal surface necessary, and for this reason I cannot recommend this method of heating the water in such cases.

When this plan is adopted, it is always advisable to select a form of boiler that can be easily cleaned, every portion of its internal surface being accessible; at the same time the fire ought not to act on the lowest portion of its external surface. The ordinary saddle boiler, or a simple cylindrical boiler with one flue through its middle, in which the fire is placed, will answer well, if care be taken that there are a sufficient number of man-holes to enable every part of the inside to be got at for cleaning.

The circulating pipes connecting the boiler with the tank must be of ample size, and they must rise or fall the whole way, that is to say no portion of them must be horizontal. The rising pipe must leave the boiler from its highest part, and enter the tank as high up as possible, provided always that its orifice is covered by the smallest amount of water that it is ever intended to heat. The return pipe should leave the tank close to its bottom, and on the opposite side to that at which the rising pipe enters the tank. It must enter the boiler as low down as possible, and when a saddle boiler is used, it must be connected with both limbs of the saddle.

As regards the most advisable dimensions for the

heating surface of the boiler and of the fire-grate, a good and safe rule is to allow one square foot of fire-bar surface, and six square feet of boiler heating surface, that is to say surface of boiler exposed to the action of the fire, for every barrel of water required to be heated in one hour. I may add that this plan is better adapted for heating washing water in large breweries than for brewing water.

In the fourth method, the water is heated by means of the exhaust steam from the steam engine, thus utilising a source of heat which would otherwise be entirely wasted. This exhaust or waste steam may be utilised by passing it into ordinary steam coils or jackets, such as are included under our fifth head; but in that case there will be a little back pressure on the engine, which some consider objectionable. In order to avoid this back pressure, some one of those inventions must be adopted which have been perfected of late years for the special purpose of heating the feed water for the boiler by means of the exhaust steam from the engine.

By means of one of these feed water-heaters, as they are called, the water is heated in a vessel which answers the same purpose as the boiler used in our third method, and which is similarly connected with the hot water tank by means of circulating pipes.

In connection with this method of heating water, and as a practical hint to those brewers who study economy of fuel, I may mention that sufficient exhaust steam is wasted during the grinding by means of a high pressure engine to heat the water required for the mash.

The fifth and last method, in which the water is heated by means of steam circulating through pipes or jackets, is probably not only the most convenient, but also the one that is most universally applicable.

Two things are necessary in order to make sure of obtaining the highest heating effect upon any given surface of pipe or jacket, viz., the perfect expulsion of the air as soon as possible after the steam is turned on, and, secondly, the keeping of the steam space in the coils and jackets as free as possible from air and from condensed water.

Postponing, for the present, the consideration of steam jackets as appliances better adapted for boiling worts than merely for heating water, I shall, in this place only discuss the method of heating by means of steam pipes. No doubt the brewing water can be heated in the most perfect manner in a steam-jacketed copper, but well-constructed coils are equally cleanly and effective, and their cost is a mere fraction of that of the steam-jacketed copper.

The coils may be made either of copper or of the best lapwelded wrought-iron steam pipe. Cast-iron pipes cannot be depended upon for this purpose, being liable to fracture.

If the back is of iron and the coils of copper the latter should be supported on a wooden frame, so that the copper may be as far as possible prevented from coming in contact with the iron, for if such contact is permitted in the presence of steam or hot water, the galvanic action set up will honeycomb the metal. For the same reason the copper ends of the coils must be carried to the outside of the tank before they are connected with the iron steam main or waste pipe.

If the coils are of wrought-iron all the supports and connections should be of iron also.

Any arrangement of steam pipes, whether in the form of coils or zigzags, can be easily kept free from con-

densed water, provided they incline downwards from the steam inlet to the outlet in a tolerably uniform manner. The outlet should be provided with a cock or valve, in order to regulate the exit of the water as it condenses, and if the length of the pipe is properly proportioned to its diameter, the cock or valve, when once regulated so as to allow the water to escape with sufficient rapidity, will require but little further attention.

For the purpose of simply heating water up to 212° F., a cock or valve answers quite as well as a steam trap, and has also the advantage of allowing the air to escape more freely; and it must be borne in mind that the expulsion of the air under the circumstances is of the very highest importance.

In order that the air may be perfectly expelled from the pipe, and the full amount of heating power obtained from its surface, the diameter of the pipe must be proportioned to its length, and the total surface must be proportioned to the amount of heating it has to accomplish.

The following table gives the sizes and lengths of steam pipe required to heat the water in two hours, the working pressure in the steam-boiler being taken at forty pounds per square inch.

Barrels heated from 60° to 212°.	Diameter of Pipe.	Length of Pipe.
10	1¼ inches	35 feet
20	1½ ,,	55 ,,
30	1¾ ,,	70 ,,
40	2 ,,	80 ,,
50	2¼ ,,	90 ,,
75	2½ ,,	120 ,,
100	3 ,,	135 ,,

The above dimensions are given for tinned copper pipe. If the coils are made of wrought iron the surface area of the coils must be increased by one fourth.

As to the most suitable materials of which to make the tank, my remarks on the tanks for cold water apply with equal force; and I think a brewer will not go far wrong if he chooses cast iron, and has the plates jointed as I there recommend. The tank should be carefully clothed with felt, or with some one of the well-known non-conducting compositions, so as to keep in the heat, and it must also be covered over. A light wooden cover will do, but the best plan in the case of cast iron tanks is to cover them with cast iron plates similar to those of which the rest of the tank is made. In all cases the cover of the tank must be provided on the one side with a large man-hole, fitted with a moveable cover, and on the other side with a large shoot, passing up through the roof of the brewery, so as to carry off the steam. This shoot should have a slide or other arrangement by which it can be closed. When the water is being heated both the man-hole and shoot are kept closed; when it is desired to cool the water, this may be effected very rapidly by opening them.

Another very convenient arrangement for cooling the water in those cases in which the whole of it must be boiled, consists of a coil of pipe fixed on brackets round the tank near its upper edge, and so placed that it will be just covered with the water when the tank is charged. By passing cold water through this coil the temperature of that in the tank can be rapidly reduced.

A revolving stirrer is another very useful adjunct to the hot water tank, especially when it is intended to artificially harden the water. A very good form of

stirrer for the above purpose consists of a small screw propeller of about one-sixth the diameter of the tank, and driven at from 50 to 100 revolutions per minute. This screw may be made with four arms, each of them two inches wide, and sloping one quarter of an inch in its width from the horizontal. A steam yacht propeller of the correct size and proportions will answer equally well.

The plant for heating the brewing water may be arranged on two different systems. The simplest of these, and the one which is certainly the best in cases where there is only one mash tun, is to have a hot water tank of ample size to supply the whole water required for one brewing; when, however, there are several mash tuns, and at the same time the whole of the water has to be boiled before it is used for either mashing or sparging, it is often advisable to supplement a main hot water tank by as many subsidiary and smaller ones as there are mash tuns. These subsidiary tanks are supplied with the boiled water from the main tank, and in them the temperature is raised or lowered to the temperature at which it is desired to employ it. Each of the subsidiary tanks must be supplied with a cooling coil, and also with a steam-heating coil; but the latter need only be half as powerful in proportion to the size of the tank as those specified in the table.

In deciding which of the above systems it is best to adopt, one of the most important considerations consists in the quality of the water and the consequent treatment to which it will be necessary to subject it. Thus, there are very pure waters, such as some of those from the chalk, which it is not necessary to boil, and a single tank for each mash tun or set of mash tuns to be mashed at

the same time is in this case all that is required. At the same time, if it is intended to harden the water, and not to boil it, the tank must be provided with a stirrer.

Those waters that contain more or less organic matter, must be boiled for ten or fifteen minutes, and this ebullition alone is sufficient to ensure the solution of the hardening material without the assistance of a stirrer. It is advisable, however, in this case to provide the tank with a cooling coil, so as to avoid the necessity of the addition of any cold unboiled water.

Lastly, there are some waters which contain iron or other impurities precipitated by boiling, and which it is necessary therefore to allow to subside before the water is used. In such cases the large main tank, supplemented by a subsidiary tank for each mash tun or set of mash tuns to be mashed at one time, is by far the best arrangement. In the main tank the water is boiled, hardened if necessary, and the precipitated impurities allowed to subside; the clear water is then run as required to the subsidiary tanks, in which the temperature is regulated by means of the heating and cooling coils already described.

The hot water mains required in a brewery are as follows :

From the brewing water hot liquor back or copper a main of ample dimensions, giving off a branch to each mash tun. If there is an external mashing machine, each of these branches must be divided into three ; one, the full size of the pipe, going to the external mashing machine, and two smaller branches, one of which supplies the sparger, and the other the underlet. If there is no external mashing machine, two subsidiary branches are sufficient for each tun, one large one to supply the

mashing water through the underlets, and a smaller branch to supply the sparger.

There should be a branch from the brewing water main also to supply water for washing or sparging the hops and this branch can also be used to supply boiled water for making up the length of any gyle which may have run out of too high a gravity. All the above mains are best made of tinned copper pipe.

From the hot washing water tank a main should be taken and conducted throughout the whole brewery, giving off branches at convenient intervals for supplying boiling water for washing all the vessels and utensils, and for flushing out all wort and beer pipes and mains. This main and its branches may be of either cast or wrought iron. Sluices or cocks must be placed on all the branches, with unions for connecting the lengths of hose required for washing out tuns and other vessels.

A separate main should be taken to the cask washing shed direct from this tank, unless a separate hot water tank is provided for supplying water with which to wash the casks.

CHAPTER VI.

MACHINERY EMPLOYED IN PREPARING THE MALT AND DELIVERING IT TO THE MASH TUN.

TURNING now from the plant required for the preparation of the water, to that which is necessary to prepare the malt for the mashing machine, the first requirement is to convey the malt from the carts or trucks in which it arrives, to the brewery malt store. This is generally accomplished by means of one of the numerous forms of sack hoist, which may be driven either by a special donkey engine or by a shaft from the main engine.

When it is intended to store the malt in bulk it is sometimes convenient to shoot it from the sacks into a hopper on the ground floor, and to convey it to the malt store by means of a Jacobs ladder, but the more usual course is to raise the malt to the store in the sacks in which it arrives.

In selecting a sack hoist the most important considerations are that it should have ample power, and that it should be provided with an automatic arrangement for preventing the sacks from being carried over the top pulley.

The friction hoists appear to be the best, but the friction arrangements must be such as to leave an ample margin of power or they will give constant trouble. Some of the patent hoists combine safety and efficiency in a very remarkable degree, and at a very moderate cost.

Sack hoists should be speeded to raise the sacks at the rate of about 170 feet per minute. In large breweries double tackle sack hoists are advisable and save labour. They will of course raise the sacks at double the speed of the single tackle hoists, and two men are required whether the double or single tackles are employed.

Whether the malt is taken into the brewery by means of a sack hoist, Jacobs ladder, or in any other manner, it is conveyed first to the malt store, the requirements in the construction of which I will next proceed to consider.

The precautions which must be adopted in storing malt in order to prevent its deterioration are very simple but it is extraordinary how often these precautions are entirely neglected in the construction of breweries. The immense importance of having a good malt store is evident if we consider that malt stored for more than a few days in a badly constructed store deteriorates rapidly, and the beer produced from badly stored malt will inevitably be of inferior quality.

The malt store in too many breweries is simply an open room to which the external air has free access, and I have occasionally found that even such obvious precautions have been neglected, as the exclusion of steam from the brewery, and leakage from the roof, or the prevention of contact between the malt and damp external walls.

Besides the attacks of vermin, such as rats, mice, and weavil, there is only one thing that can injure malt, and that is its absorption of moisture. Unfortunately malt absorbs moisture freely and has a strong attraction for it, whether it comes in contact with it in the form of the invisible vapour always existing to a greater or lesser extent in the air, or in the more palpable forms of steam, or of the damp which is generally slowly percolating through external walls.

The construction of a good malt store therefore involves the exclusion of vermin, and also of moisture in all its forms, and of course the longer the malt has to remain in the store, the more perfect must that exclusion be. In most breweries at the present day, the brewery malt store is only intended to contain a few weeks' consumption, the malt being sent in from the maltings as required. In this case the malt is kept in the sacks in which it arrives, but even so, bins made as air tight as possible are advisable. The ceiling of the bins should be of lath and plaster, and the floor should be iron-tongued, or still better, asphalted; unless indeed, the room below is perfectly dry, and always free from steam. External walls should have a coating of asphalt, and the partitions of the bins should be made of well-seasoned floor boards, iron-tongued, and nailed to vertical studding. The whole interior surface of such malt bins should have an occasional wash of lime, slacked in hot water and applied fresh.

In malt stores in which the malt is to be stored for many months, more stringent precautions ought to be taken. Some of the best of these stores are constructed of thin boiler plates, rivetted together, caulked, and well painted. These are of course absolutely damp and

vermin proof, and the external air can be entirely excluded except when the doors are opened; for the latter may be made to close against a piece of india-rubber or thick felt, and with a fastening which presses them firmly up. Nothing can be better than these wrought iron malt stores, and an occasional coat of paint is all that is required to keep them in perfect order. They are, however, very expensive.

Cheaper malt stores, also perfectly air tight, may be made by lining ordinary wooden bins with zinc.

The necessity for air tight malt stores is evident, when we consider that malt when taken off the kiln, if perfectly cured, contains about 1 per cent of moisture, and that by the time it arrives at the brewery the moisture will have generally increased to at least 2 per cent. and very frequently to 3 per cent. Now it is certain that malt containing 5 per cent and upwards of moisture deteriorates with considerable rapidity on keeping, so that an absorption of only from 2 to 3 per cent. of moisture in the brewery store, is enough to endanger the soundness of the malt.

The malt in its passage from the store to the mashing machine has to be cleaned, ground, and ultimately deposited in the grist case, and to effect these operations Jacobs ladders, conveyors, screens, and malt mills, are required.

The Jacobs ladders should always be of ample power, and if of great height the cups should not be too large or too close together, but in due proportion to the frictional power, and to the speed at which the whole is to be driven. The driving pulley should always if possible, be attached to the top pulley of the Jacobs, so as to utilise the bite obtained by the weight of the belt

and cups, and there should be an arrangement by means of which a considerable amount of slack of the Jacob belt can be taken up, without shortening the latter. This is generally effected by means of a screw so arranged as to lower the lower pulley of the Jacob for some inches.

The screw conveyors used for conveying malt horizontally need no special description, and provided the pitch of the screw corresponds to the speed, and the power is ample in proportion to the amount of malt to be conveyed, they give little trouble. The same construction both ot Jacobs and screw conveyers is adapted for both whole and ground malt.

There are a number of different forms of malt screen, but they may all be classed under two heads—viz., the flat and the cylindrical. Of the flat screens those on Boby's system with moving discs are the best, and for the original screening of the malt after it leaves the kiln these screens are by far the most efficient. For screening the malt as it passes to the malt mill the best forms of circular screen are preferred by some, but Boby's flat screens are cheaper, more easily cleaned, and certainly quite as efficient. In the circular screens the malt first falls on a fine screen, through which the dust passes into the dust chamber. The next section of the screen is coarser and allows the small corns to pass through, and the third and last section of the screen allows the rest of the malt to pass, retaining only the stones and rubbish, which fall from the open end of the screen into a receptical fixed to receive them. These cylindrical screens should be provided with a rotating brush placed parallel to and rotating against one side of the screen, which it keeps clean and free from adhering dust or

other matters. Flat screens are generally arranged so that the stones are first separated, the malt is then graded and the dust separated as with the circular screens.

As small pieces of iron such as nails may pass through the second and third portions of the screen if they are not larger than the malt corns, and as even when of such small size they seriously injure the rolls, it is very advisable to arrest them before they reach the screen. For this purpose permanent magnets are used, and a simple and convenient plan is to thrust them through holes in a moveable portion of the cover of the shoot which conveys the malt to the screen. These magnets are fastened to this moveable cover, and when it is necessary to remove the pieces of iron adhering to them, the cover is thrown back, and the ends of the magnet projecting from it are then cleaned without difficulty. Armatures should be provided to maintain the strength of the magnets when not in use. Of course, soft iron magnets and a galvanic battery may be substituted for the permanent magnets, but with probably no advantage sufficient to counterbalance the extra trouble of keeping the battery charged. Some special arrangements have been patented, but I do not think they are so good as the above simple plan, which is equally cheap and effective and is open to all.

For the further cleansing of the malt, more especially from adherent dust, mould spores, and other minute organisms, machines have been invented, and are in use in some breweries, which by means of brushes remove all adherent particles. When brewers are so unfortunate as to be compelled to use mouldy malt, these machines are no doubt of use, but although they

greatly improve its appearance it must not be for a moment supposed that they convert mouldy into sound malt, as the mischief is far too deep seated, to be cured by such superficial, or in fact by any known means. Of some use in the hands of the brewer, these machines in the hands of the maltster may lead to serious mistakes as to the quality of the malt, and I should be very sorry to purchase malt from any maltster who used one.

A friend of mine has just invented a new malt cleaning apparatus and screen which seems to be an important improvement on old forms, but I have not yet seen it in practical operation.

The malt having been cleaned and the small corns separated from the full sized ones, it is ready for the malt mill, and should be delivered by the screen directly into it or into a small hopper the breadth of the mill, and delivering into the rolls through a gate, forming a narrow slit, so as to deliver the malt evenly the whole length of the rolls. In this way the regulation of the feed to the screen and the passage of the malt over the latter helps to govern, regulate, and equalise the delivery of the malt into the mill.

Although no restrictions are now imposed by the excise on the form of the malt mills used by brewers, the latter still generally adhere to the varieties of smooth roller mill, and it seems very doubtful whether in the case of malt, any other kind of mill is so well adapted for thoroughly crushing the contents of the corns, with as little breaking down of the husk as possible. The mills, however, with only two smooth rolls ought to be replaced in all breweries by mills with four smooth rolls, and whether there are two or four rolls they ought to be

geared together in pairs, and driven so that their surfaces run at equal speeds. The rolls should be of moderate diameter, for if the diameter is large there is a great waste of driving power. The moveable bearings should be provided with stiff bent steel springs, to allow of sufficient play to prevent the breakage of the mill, when by accident a piece of any hard substance passes through it. India rubber cushions are sometimes used for this purpose, but have the serious objection of soon becoming softened and spoilt by the oil used in lubricating the bearings.

I have said that all malt mills ought to have four smooth rolls, constituting in fact a double mill, one pair of rolls being set when in work to a wider gauge than the other. I have already described how the small corns of malt are separated from those of full size, and the object of this separation, is to enable the full sized corns to be passed through that pair of rolls which is set so as to crush them sufficiently, but not too much, while the small corns pass through the other pair, which are set very close, so as to ensure the disintegration of the structure of every corn, however small it may be. When malt made from small foreign barley is used, the whole of it may be advantageously passed through the fine set pair of rolls, with the small corns from the best malt, for these malts from cheap foreign barleys, although sound, are generally of a hard character, and, unless they are ground very fine, the whole of the extract cannot be obtained from them. Of course, the same objects may to some extent be attained with a single pair of rolls, by passing the large malt through them first, and then setting them up close and passing the small malt through, but this is not only

very troublesome, but under these circumstances the different varieties of the ground malt are not thoroughly mixed, and such good results cannot therefore be expected as when the malts are ground simultaneously. Brewers will find that the erection of one of these double mills is a most excellent investment, for it will certainly increase their extracts by two or three lbs. per quarter, and, if they use cheap foreign malts the increase of extract will be far larger.

Some makers add a feed roll to their malt mills, but I consider feed rolls to be not only useless but objectionable. When a flat screen is used the malt as I have already observed is best delivered direct from it into the rolls, and with cylindrical screens, the small hopper with a gate which I have already described delivers the malt into the rolls in a far more perfect manner than any form of feed roll.

As the malt is ground it either falls directly into, or it is conveyed to the grist case, which must always command the mashing machine.

The grist case is generally made of pine or deal carefully planed and jointed so as to leave no uneven surface; any such impediment would prevent the malt running freely from it to the mashing machine, and for the same reason the bottom must have a sufficient slope. As, however, the best-seasoned wood is liable to shrink and warp, it is desirable to line the case with sheet zinc, which can be done at a small expense, and which effectually prevents any dampness which might otherwise be caused by the steam rising from the mash tun.

As every particle of malt must be swept with care from the grist case at every mash, and its mouth, where it joins the mashing machine, even more assiduously

cleansed from any atoms of damp malt which may adhere to it, a conveniently placed and sized manhole must be provided at or near the top of the case and also hand holes at the bottom just above the mashing machine.

With Steel's or similar mashing machines a very good plan is to have a short moveable box or shoot interposed between the slide at the bottom of the hopper, and the slide of the mashing machine. This moveable shoot is about a foot long, and is taken away as soon as the mash is completed. The mouth of the hopper is thus left exposed, and can be cleansed easily and thoroughly, as can also the mouth of the mashing machine; and there is this further advantage, that all connection between the grist case and machine being cut off, there is no danger of steam passing through the latter into the former during the sparging, through leaky or imperfectly closed slides.

Although I generally prefer grist cases made of wood and lined with zinc, wrought iron, either galvanised or otherwise, is sometimes used as the material for their construction. If wrought iron is used I certainly think it should not be galvanised, as the galvanising is of no advantage, and the rough surface generally produced by it is distinctly objectionable. Thin boiler plate with a very smooth surface is best. The joints should be flush rivetted, and every precaution taken to keep the inner surface as smooth as possible. The inner and outer surfaces of these iron grist cases should be well painted, and every means taken to keep the interior free from every trace of steam and absolutely dry. This is not always so easy in cold weather, and in a close, ill-ventilated brewery; and as every particle of steam or

vapour which finds its way into these iron grist cases condenses instantly on the inner surface, it is much more difficult to keep them dry than wooden ones. I need not point out the fatal mischief that may arise from a slimy coating of condensed steam and malt dust forming on the inner surface of the grist case.

The mechanical leveller, which consists of a simple board revolving on a central shaft near the top of the hopper is frequently a very convenient adjunct to the grist case. It should be driven by a belt, and saves all the trouble of levelling by hand, which is otherwise often necessary when the grist is taken to the hopper by an elevator or screw conveyor.

I will conclude this chapter by a recapitulation of the apparatus described, giving the relative positions in which the various machines, &c., should be placed. Commencing with the malt in the store; this should be introduced into a hopper of sufficient capacity commanding the screens and mill. It is in the shoot from this hopper to the screens that the magnets should be placed in the manner already described.

As regards the position of the mill, I prefer placing it on the ground floor so that it may be as solidly fixed and supported as possible. It should also be close to the engine room but partitioned off from it so as to exclude dust from the engine. The engine man can thus see to the grinding and to his engine at the same time, and much trouble and labour is saved.

The ground malt is then carried to the grist case by the Jacobs ladder, supplemented if necessary by a screw-conveyor.

It is most important to exclude steam and damp in every form from every portion of the plant and

machinery treated of in this chapter, and every precaution must be taken to secure this object. All pockets or corners in which malt either ground or unground would be liable to lodge, must be avoided, and the whole arranged so that hoppers, shoots, screens, mills, Jacobs, conveyors, and grist cases can be easily swept clean out. When the plant is only used once in the twenty-four hours every particle of the malt for each brewing should be carried forward until it is deposited in the mash tun, but in breweries where the brewing is continuous, as at Burton, the above precaution is not generally practicable or indeed necessary. In that case it is sufficient if the whole be swept forward each time there is a pause for cleaning up. Few brewers appear to be aware how much mischief is caused by very small quantities of stale malt, and it is to impress on them the necessity of avoiding all accumulations of malt or malt dust, that I have dwelt so fully on the above details.

CHAPTER VII.

MASH TUNS.

MASH tuns are made either of wood, of wood lined with copper, of cast-iron, or of wrought-iron. In constructing a mash tun, of whatever material, it must always be borne in mind, that owing to the chemical changes which take place while the mash is in the tun, it is of the greatest importance to retain the heat, and not to allow it to pass away through the sides or bottom of the tun. For the same reason the top of the mash must be protected and kept as warm as possible.

I will now proceed to consider the construction of mash tuns of the above materials and the special precautions which are necessary in the case of each material.

In wooden tuns the staves should be made of the best English oak, and the bottoms of Dantzic fir. The staves should be not less than two and half inches thick for small tuns, and the thickness must be increased for larger tuns in proportion to their size. It is very important that only the best English oak should be employed in the construction of mash tuns. I have known instances in which, owing to foreign oak having

been substituted, the tuns have become quite rotten in the course of a very few years. I need scarcely remark that whatever wood the tuns may be made of, they become totally unfit for use directly there is the slightest appearance of decay. Great care is required to keep wooden tuns clean, and both in respect of the ease with which they can be kept clean, and of their complete freedom from all liability to decay, cast-iron tuns certainly possess great advantages over wooden ones.

The sides of a wooden mash tun, like those of all vessels constructed on the same plan, must have a certain slope, in order that the joints may be rendered tight by driving the hoops. In old-fashioned tuns, in which the mash was made by hand and spargers were not employed, it was a common practice to make the sides of the tuns slope outwards. This method of construction is quite inadmissible where spargers are made use of. The sides of all modern tuns are therefore made to slope inwards; but this slope should be as slight as is compatible with the effectual closing of the joints by the driving of the hoops, as the decrease in the diameter of the tun from below upwards interferes with the free rise of the goods. As cast-iron tuns can be made with perpendicular sides, the goods will rise more freely in them than even in the most carefully constructed wooden tuns.

In Scotland the favourite construction is the wooden mash tun lined with copper and certainly these tuns if well made possess advantages as regards the two important points of cleanliness and durability. The objections to them are their costliness and the difficulty of fitting them in any satisfactory manner with internal rakes.

The chief precaution which must be observed in their construction is to line them with sufficiently stout copper. Copper sheet of 5 lbs. to the superficial foot answers well but it should not be thinner, and some brewers would probably prefer 6 lbs. sheet. Tuns lined with thinner copper are most objectionable, for if the metal is not thick enough to stand for any length of time the trampling of the men in throwing out the grains, the surface becomes irregular and sooner or later the joints begin to leak. The leakage, if ever so slight, results in the formation of foul deposits of putrid wort between the copper and the wood, minute particles of which are liable to be forced back into the empty tun by the weight of the men when cleaning it, and of course the slightest trace of such an impurity affects the soundness of the mash most injuriously.

In order to reduce as far as possible the risk of any leakage through the copper lining remaining undetected, the wooden bottom of the tun should not be jointed water tight, so that any leakage may at once appear externally, and give notice of the mischief that is going on.

These tuns, when lined with copper of sufficient thickness, and when this copper lining is so perfectly jointed as to be absolutely watertight, are very durable, and they can also be kept absolutely clean, more easily than perhaps any other construction of mash tun. When therefore, the brewer decides to use outside mashing machines only, he cannot well do wrong in adopting these copper lined tuns. My experience, however, induces me to believe that every mash tun should be provided with internal rakes, and for brewers who agree with me on this point, the choice practically lies between wooden tuns and those made of iron.

Cast iron tuns have been in use in this country for a very long period, but for many years they were to be found almost exclusively in the large porter breweries. The great objection of ale brewers to the use of cast iron mash tuns has arisen principally from the fear that the mash would be injured by contact with the metal. Long practical experience and most careful experiments have, however, convinced me that no injury arises from this cause so long as the surface of the tun is free from rust. The sugar in the mash is undoubtedly capable of dissolving oxide of iron; but it has no solvent power whatever on the metal itself. And after the tun has been used a few times the surface of the cast iron becomes modified in such a manner by the action of the wort that there is no longer any danger of its rusting, provided the tun is kept in pretty constant use. If a cast iron mash tun has to stand idle for any length of time a little rust may make its appearance. This should be carefully removed by scouring, and the surface of the tun then washed with a solution of tannic acid. This treatment leaves the tun coated with an insoluble tannate of iron, and after rinsing with water it may be at once used for brewing even first-class pale ales with perfect safety.

In the construction of iron tuns no other metal than iron or its combinations should be used. Cast iron, wrought iron, or steel, when brought together in the mash tun are not liable to set up galvanic action; but a copper or brass false bottom placed in an iron mash tun must inevitably produce this result. I do not myself believe that galvanic action has any perceptible direct influence on brewing operations, but there can be no doubt as to its destructive powers in the case of metal

vessels. The contact of copper and its combinations with iron promotes the rusting of the latter, and certainly increases the probability of its solution in the wort. No possible object can be gained by introducing other metals into the construction of iron tuns, and there is therefore every reason to make all the metal portions and fittings of an iron tun, as far as possible of iron or steel, the bearings of the internal rakes being, I think, the only exception which is necessary, and which must therefore be tolerated.

Cast iron tuns must be made of metal of such quality as is not liable to crack on the sudden application of heat or cold. Many of the cheaper sorts of iron are incapable of standing sudden changes of temperature, and brewers, who tempted by the low offers of inexperienced founders, have put up iron hot liquor backs, mash tuns, or hop backs, constructed of such inferior iron, have occasionally had to suffer for their false economy. It is those who have had the misfortune to be misled in this way, that we sometimes hear complaining that cast iron vessels are liable to crack. There is not however the slightest risk of cast iron vessels cracking, if they are made of a proper combination of different kinds of iron. Brewers' Engineers of standing and experience, may be trusted to use the proper quality of metal, and those who have foundries in London, are at present in a very good position to supply castings of the requisite character.

The plates, of which cast iron tuns are built up, should have their flanges planed, and the joints made watertight, in the manner I have already recommended in the case of liquor backs.

Cast iron mash tuns must be covered with some non-

scale. The metal they are made of must be homogeneous and it must have a clean smooth face, the joints must be flush, and flush rivetted, and great care must be taken to keep the surface in good order, so as to prevent scaling or pitting. This is effected by scouring the surface occasionally with sand, and then washing it with a solution of tannic acid as I have already recommended in the case of cast iron tuns.

Steel is, I think, a better material than wrought iron as it is more homogeneous and it will probably come into use in breweries for many purposes sooner or later.

The other precautions to be adopted are the same as with cast iron tuns, except that the metal being much thinner, there is less absorption of heat if steam is not used, and less heat given out from a steam heated tun. As however heat passes very quickly through them, great care must be taken in clothing these wrought iron tuns with felt or other non-conducting material.

All mash tuns of whatever materials they are constructed require carefully made covers, in order to protect the top of the mash as far as possible, from the cooling influence of the atmosphere. Taking all things into consideration I think wood is the best material for the construction of these covers, and Dantzic, Christiania or Archangel firs are perhaps the best woods to use.

The form of cover I prefer consists of a flat top extending to within about four or five feet of the circumference of the tun, and supported just high enough to allow the sparger and the rake gearing to work freely below it. Ribs of wood recessed on each side run from this cover and the framing on which it rests to the top of the tun, or if the rakes have cogs running round the top of the tun, to a curb fixed just outside, and high enough to

clear the gearing. In moderate sized tuns these ribs, and the frame on which the cover rests, can be so framed together as to be self supporting, but in very large tuns a further support from beams passing above the covers is necessary. The cover is completed by moveable wooden segments, resting on the recessed ribs, and these segments must be made small enough to be easily removed by one person.

In some breweries the flat wooden cover is of the same diameter as the tun, and supported about 24 to 30 inches above it; sliding shutters are then provided to close the vertical space between the tun and the fixed cover. This form of cover leaves too much vacant space above the mash, and it is difficult to make the sliding shutters fit tightly or move with facility.

Expensive copper covers are used in some large breweries, but are objectionable unless they are carefully non-conducted with felt, for the copper allows the heat to pass through it rapidly, the steam from the mash condenses on the cold surface, and a shower of comparatively cool water is precipitated on to the mash which might almost as well be left uncovered. When well clothed with felt these covers are no doubt effective, but I see no advantage except their durability, to compensate for their heavy cost. Whenever they are used however the framing on which the copper rests must be made of brass or gunmetal, for iron frames in such a position are oxidized and destroyed by the galvanic action with wonderful rapidity.

When mash tuns are conveniently placed for the discharge of the grains through the bottom of the tun, they may be provided with valves or slides fixed to the bottom, and some labour is saved in this way, but only

when the position of the tuns is favourable to this method of discharging the grains. In all other cases I adhere to the old plan of casting out the grains over the top of the tun, and I strongly object to valves delivering into screw conveyors, which generally cause delay, and waste of time and engine power, and are always recepticles of filth.

As regards the capacity of mash tuns, the rule is to allow from three and a half to four barrels for each quarter of malt. In making contracts with engineers and others for the erection of mash tuns, brewers should always bear in mind that some of those who profess to cut their prices very fine, may do so by reducing the allowance per quarter to as little as three barrels. In making contracts, the better plan is therefore to insist on the absolute dimensions of the tun being stated, and not to trust merely to the engineer undertaking to erect a tun which will contain a mash of so many quarters. The brewer can easily calculate for himself the exact capacity he requires for any number of quarters. The malt itself, when mashed, occupies a space of as near as possible one barrel per quarter, if, therefore, the thinnest mash that a brewer ever intends to make contains two and a half barrels of water per quarter, the exact number of barrels the tun must contain is three and a half barrels per quarter; of course a small allowance must be made for the space occupied by the false bottoms, and machinery, &c. A very good plan is to calculate the size of the tun at three and a half barrels per quarter, and then add an allowance of three inches to the depth of the tun.

The size of the mash tun relatively to that of the fermenting vessels may be determined on two different

principles; for it may either be decided to always mash the same quantity of malt, and to vary the "length" of the beer run, and consequently the size of the fermenting vessels according to the strength of the various beers required; or, on the other hand, the same "length" may be run in the case of all qualities of beer, variation in strength being effected by varying the amount of malt mashed. In some respects the latter plan is the most convenient, as the fermenting and cleansing vessels are on that system always fully utilized. It has one great disadvantage, however, for if the best attainable depth of goods is secured when the strongest beers are mashed, it is evident that in the case of the weaker beers the depth of the goods must be very much too small.

With deep tuns a greater variation in the amount of malt mashed is permissable, than with shallow tuns, but every brewery ought to have at least two mash tuns, one of which should be of about two-thirds the capacity of the other. Thus with a 20 quarter plant a brewery should have one 12-quarter, and one 8-quarter tun. With these two tuns any quantity of malt, from 5 up to 20 quarters, can be mashed without unduly reducing the quantity of goods in the tun, provided the tuns are of the correct proportions given in the tables which follow. Thus I should mash five to eight quarters in the small tun, and from nine to twelve quarters in the large tun. Nine quarters in the latter and five in the former makes a fourteen quarter mash, and so on up to the two full tuns containing twenty quarters.

The proportions of a mash tun is a matter of great importance. When the mashing is effected by means of a rake mashing machine only, the depth of the tun is governed by the diameter of the revolving rakes, and

this diameter is to a certain extent again governed by the diameter of the tun; for if the diameter of the rakes is too great in proportion to that of the tun, they cannot be made to revolve close enough to its sides to ensure a perfect mash. This remark does not, however, apply in the case of the largest mash tuns, in which the mash is effected by means of double rakes or chain mashing machines. Another point which must be borne in mind is, that when the mashing is performed either by hand or by any form of rake machine the goods are never sufficiently light to rise to more than a certain very limited height. Bearing these various considerations in mind, the following table gives good practical proportions for mash tuns in which the mash is effected entirely by means of rakes. This table represents also the proportions of the shallowest tuns which I consider can be worked with advantage under any circumstances. The sizes are calculated for three and a half barrels per quarter, with a small allowance for false bottom and machinery.

Quarters of Malt mashed.	Diameter of tuns.		Depth of tuns.	
	ft.	in.	ft.	in.
5	5	10	4	0
8	7	1	4	3
10	7	8	4	6
12	8	3	4	8
15	9	1	4	10
20	10	1	5	2
25	11	1	5	4
30	11	11	5	6
40	13	5	5	10
50	14	6	6	2
75	16	8	7	0
100	18	6	7	8

When outside machines are used either alone or in

conjunction with rakes the depth of the mash tun in proportion to its breadth may be advantageously increased. This use of outside machines in conjunction with inside rakes is, I consider, by far the most efficient arrangement of mashing machinery. The following table gives the dimensions of these deeper tuns, and I do not think it is advisable to much exceed the depths given in it. The dimensions are calculated at three and a half barrels per quarter, with a small allowance for machinery and false bottoms as in the first table :—

Quarters of malt mashed.	Diameter of tun.		Depth of tun.	
	ft.	in.	ft.	in.
5	5	2	5	1
8	6	4	5	5
10	7	0	5	6
12	7	7	5	8
15	8	4	5	10
20	9	4	6	1
25	10	2	6	5
30	11	0	6	6
40	12	6	6	9
50	13	9	7	0
75	16	3	7	6
100	18	1	8	0

One hundred quarters is the largest tun I should advise brewers ever to erect, and probably 75 quarters is a sufficient capacity for the tuns of even the largest breweries.

The false bottoms of mash tuns may be made of wood, of stout sheet copper fastened to wooden bearers, of cast brass or gun metal, or of cast iron. In wooden mash tuns the false bottoms may be made of either of the above materials, but, as has been before observed, cast iron bottoms are the only ones adapted for use in tuns made of that metal.

Whatever the false bottoms are made of they must be securely fastened down to prevent all possibility of their being displaced, an accident which is sure to cause serious trouble and loss, and when there are rakes in the tun, not unfrequently involves the breakage of the machinery. Wooden false bottoms, or those made of sheet metal fixed to wooden bearers, are liable to float up unless well secured, but even with heavy cast metal bottoms, the only way to avoid all chance of accident is to fasten them securely down.

Wooden false bottoms are so troublesome, and are such a source of constant expense, that they are now seldom if ever used. False bottoms made of sheet copper must be of good stout metal, well screwed down with brass screws to stout oak bearers, and perforated with a very large number of small holes.

False bottoms of cast brass or gun metal are expensive, but when used in wooden tuns this is the only objection that can be raised against them. At the same time it is doubtful whether any advantage is secured by their use, which compensates for their heavy cost as compared with those of cast iron.

As I have already said cast iron tuns must be fitted with cast iron false bottoms, and I can see no disadvantage which can arise from their use in wooden tuns also.

Cast metal false bottoms may be either perforated with numerous small round holes or they may be slotted. If round holes are used they must be well countersunk, and as numerous as possible ; their size must not exceed one eighth of an inch, and the distance between their centres must not be more than one inch. These round holes must be drilled (not cast) in the

plates, so that their surface may be smooth. False bottoms have been recently introduced made of cast iron, with gun metal plugs of about half an inch in diameter driven firmly into holes in the plates. These gun metal plugs are perforated with excessively small holes, and as there are a large number of these perforated plugs in proportion to the surface, these bottoms are very efficient, giving good drainage and very bright worts. They are, however, expensive, and I fear that in the course of a few years the galvanic action caused by the contact of the two metals, will eat away the iron and so loosen the plugs, when these bottoms will, of course, become useless.

Slotted false bottoms of cast-iron certainly possess the advantage of a much larger drainage area than those with round holes, but as the slots must be cast owing to the nature of the material, and as they are therefore always more or less rough, and of uneven width, I do not think that the extra drainage surface compensates for the above defects. They answer fairly well when outside mashing machines only are used, but if there are rakes in the tun, these cast iron slotted bottoms are most objectionable, as they allow a considerable quantity of the goods to pass through with the worts.

Nothing can be better than some of the beautifully made gun-metal slotted false bottoms, in which the slotts are cut perfectly smooth and true by means of special tools. The only objection to them is their great cost.

The false bottom plates, of whatever material they may be made, must be supported so as to leave a clear space of from one and a half to two inches between them and the bottom of the tun. Wooden plugs, driven into sockets cast on the plates, is the common and most

convenient means of providing this support in the case of cast bottoms. Wooden and sheet copper bottoms are supported on their bearers, which should be cut away in a sufficient number of places to allow a free flow of wort underneath them between the adjacent plates.

The bottom of every mash tun must be provided with a suitable number of pipes for drawing off the wort. These should be introduced into the bottom of the tun at such intervals as to distribute the draught and prevent its being too strong in any one place. The number of holes must therefore vary with the size of the tun. Thus for small tuns of under five quarters, two holes are usually deemed sufficient, placed on opposite sides, and distant from those sides one sixth of the diameter of the tun. In the case of somewhat larger tuns, four or more holes should be placed at equal distances in the circumference of a circle, the diameter of which is a trifle more than half the diameter of the tun. In tuns of the largest size the holes are best distributed in rows at a distance of four or five feet apart.

The pipes, after leaving the tun, may either be each conducted separately to the underback, or they may be first connected into one or more mains leading to that receptacle. I much prefer the former arrangement with separate taps on each pipe, for not only is it easier on this plan to keep the pipes clean, but the brewer can see that each tap is delivering its proper proportion of wort. The taps may be fixed to the bottom of the tun, or at the extreme end of the pipes, as may be most convenient, but I prefer the latter plan. In all cases the mains should be as straight as possible, and both mains and taps so arranged that they can be brushed through with ease. A steam pipe should also be connected with

them as with all other wort and beer mains, so that they may be frequently cleansed by blowing steam through them.

Pipes should be provided in the case of all mash tuns, by means of which hot water can be run in under the false bottoms. These are the underlets mentioned in Chapter V. as requiring a branch from the hot water main, and a simple plan is to connect the latter with the pipes I have just described for drawing off the wort. The connection between the water and wort pipes should be made close to the tun and between the tun and the wort taps. A branch from the hot water main, with a single cock on it, is sufficient and from this branch subsidiary branches are connected to each of the wort pipes. The object of this arrangement is to enable hot water to be introduced into the tun below the mash, and all tuns should be fitted with it whatever form of mashing machine is used.

CHAPTER VIII.

MASHING MACHINES, SPARGERS AND SPECIAL MASHING APPARATUS.

I NOW come to the mashing machines, a most important portion of the plant, and which, with the exception perhaps of the refrigerators, have had more inventive genius lavished upon them than any other portion of the machinery of a brewery.

The original mashing oar needs no description, but a perfect mash could not be made with it in tuns of any considerable size. Either too much water had to be used, and the mash was too thin, or else if less water was added, a thorough admixture could not be secured, as there was not sufficient power to break up the aggregations of dry malt which formed the centre of the nodular masses or balls.

In America a considerable improvement was effected by the use of long troughs instead of round tuns, and in these it was much easier to make a good stiff mash by hand.

I believe that some form of internal rake machine was the first advance upon hand mashing, and well constructed rakes are still a portion of the brewery plant, which I cannot advise brewers to dispense with.

It is, however, advisable to assist the action of the internal rakes by some form of outside mashing machine, for it is much easier to thoroughly wet every particle of malt as it runs to the tun, than to deal with it in bulk after it has reached that vessel.

Mashing machines may be classed under three heads, viz:—the various forms of internal rakes; external machines driven by power; and, finally, the so-called Automatic Mashers, in which the only power used is that residing in the falling streams of malt and water.

The earliest form of rake mashing machine consisted of a strong cross-bar stretching right across the mash tun at the level of its upper edge, and carried by a vertical shaft revolving in the centre of the tun. Light wooden bars were fixed vertically and at regular intervals to the cross-bar, so as to make a stirrer in the form of a revolving rake of the same depth and diameter as the tun. By the revolution of this rake on the central shaft satisfactory results were obtained so long as the mash was sufficiently thin, and this machine is, even now, in very general use in distilleries in almost all parts of the world. It is not, however, capable of producing the thick mash required by brewers, who have consequently rejected it in favour of the more modern form, in which a double motion is given to the rakes, and the various modifications of which are now in use in most breweries.

There are several modifications of these double action rake machines. Those adapted for small tuns generally consist of a single horizontal shaft, rotating at about the level of half the depth of the tun by means of gearing fixed to a central vertical shaft. The horizontal shaft is caused to revolve round the tun, as well as on its own axis, the former movement being effected by

gearing its outer end into a circle of cogs fixed to the inside of the mash tun, or, in some cases, to its upper edge. Rakes, *i.e.*, arms with teeth fixed across them, are placed at regular intervals along the horizontal shaft, and by their rotatory motion and revolution round the tun the grist is mixed with the mashing water.

For large tuns, two similar horizontal shafts are used instead of one. These two shafts are fixed in a frame and rotate one above the other; they are either provided with rake arms, as in the single shaft mashing machines, or the rakes are fixed to endless chains, carried by pulleys placed at regular intervals along the two horizontal shafts. These double rake machines should always be fitted with reversing gear, so that they can be caused to revolve round the tun either to the right or left. This enables the mash to be more perfectly levelled, for by reversing the rakes just before stopping them, the depression in the goods caused by their being carried before the revolving rakes is filled up.

Besides these forms of solid rakes, a very ingenious machine was introduced some thirty years ago, in which the rakes were hollow so that steam or hot water could be passed through them, and the temperature of the mash thus raised uniformly to any required degree. I have heard brewers who have used them, speak in the very highest terms of these rakes, but they were of a very weak construction, and consequently liable to break down. I believe that their liability to accidents was the reason that prevented their being generally adopted.

Of the mashing machines working outside the tun and driven by power, Steel's is by far the best, as it is also the best known. It consists of a horizontal cylinder closed at one end and open at the other. The diameter

of this cylinder is generally from eight to twenty-two inches, and its length from three to six feet. It is fixed horizontally on, or slightly above, the level of the upper edge of the mash tun into which it may project, or the mash may be conducted into one or more tuns by means of shoots. If the latter arrangement be adopted, a considerable fall must be allowed between the mouth of the machine and the top of the tun; I cannot, however, recommend this arrangement, as it is far better to have a machine for each tun. Inside the cylinder of Steel's machine a shaft passes concentrically through its whole length, and this shaft is provided with spokes placed at short and regular intervals. The length of the spokes is such that they just revolve freely inside the cylinder. The shaft is driven by a pulley outside the closed end of the cylinder, and the grist is fed into the upper side through an upright T piece affixed to the same end, the water meeting the grist through a pipe just as it reaches the cylinder. A slide that can be accurately adjusted by means of a screw regulates the fall of the malt, and the cock which regulates the water should also be easily adjustable.

Steel's machine is very effective provided it is driven at a sufficient but not excessive speed. From 120 to 180 revolutions per minute will be found to give good results; the slower speed is sufficient for machines of the largest diameter, the higher speed for small machines.

Subsequently to the time when Steel's machine was introduced, a machine working on somewhat the same principle was invented. It consists of two or more cylinders placed side by side, and each provided with a revolving shaft carrying the stirring arms. The mash passing successively through this series of cylinders.

I do not think this masher is any improvement on Steel's, and I may say the same of one or two other modifications which have been since introduced. I certainly consider that Steel's is still the very best of all external mashing machines.

The forms of automatic mashing machine which have been introduced of late years are very numerous, and the comparatively small price at which they can be erected, has recommended them to those brewers who study economy in the cost of their brewery plant.

The most effective of these machines are, Willison's and Thompson's, which are furnished with paddles, and Gregory's and Southby's, which work as effectively and without these appendages. Southby's new machine (1884 patent), is the simplest of all the Automatic mashers, and appears to be as efficient as any. In all these machines the mashing is effected by the streams of malt and water being brought into intimate contact as they flow towards the mash tun, and their efficiency depends in all cases on there being a sufficient pressure of water, and on the malt running in a steady and even stream from the grist case.

In Willison's machine the water is introduced in a thin sheet or cataract, in all the others in fine streams or jets.

The peculiar feature of Thompson's machine is the arrangement of double paddles. In Gregory's the jets of water proceed both from the external case and from a central pipe of peculiar construction. In Southby's new machine, the rows of jets are close together and are of such a form as to utilise the force of the water to the uttermost. The stream of grist also in this machine is made to descend in a thin and uniform sheet by falling on a cone above the rows of jets.

There are numerous other forms of automatic mashing machine besides those I have briefly described, but these other forms have as far as I know little to recommend them, and some of them are so inefficient as to cause heavy losses to those who use them, the mash produced by them being imperfect, and the wort deficient both in quantity and quality.

Spargers are a very simple but a very important portion of that section of the brewery plant which I am now describing, and there is probably no utensil used in a brewery which is so often allowed to become ineffective. I am sure that I am within the mark when I say that the amount of beer lost annually by the brewers of the United Kingdom through defects in their spargers, amounts to thousands of barrels.

A good sparger may be defined to be one which will revolve steadily with a small supply of water, and which will also distribute the water uniformly over the surface of the goods, so that an equal quantity falls on every superficial foot of that surface.

The holes in the sparger arms must consequently be small and numerous, and the number must increase from the centre outwards.

The following is a simple plan of ascertaining whether the sparger is delivering the water uniformly. Have a tin dish made six inches deep, one foot broad, and of half the diameter of the mash tun, and divide this dish transversely into any number of sections, by soldering in watertight partitions. Now support this dish in the mash tun a few inches below the sparger, see that it is tolerably level, and then start the sparger. If after it has been running for a few minutes, a uniform depth of water is found in each section, the sparger is working

properly, but if not the holes in the arms must be either opened or diminished in size, until a uniform distribution is obtained.

There are three modes of mounting the sparger The simplest form consists of a circular reservoir, into which the sparge water flows through a pipe from the hot liquor back. A hollow cone is fixed in the centre of the bottom of this reservoir, with its apex on a level with the top, and the reservoir revolves on a central pin fixed in the middle of the mash tun at its upper edge and reaching a short distance above the top; the arms are screwed to sockets communicating with the lower part of the reservoir, and are pierced with numerous holes.

Where rake mashing machines are employed, and geared from above the tun, the central vertical shaft has to pass through the reservoir, which consequently has to be made to revolve on friction wheels running on a small circular platform fixed to the central shaft.

In the third form the reservoir is dispensed with, the arms being suspended over the centre of the mash tun by a stuffing box from the end of the pipe which supplies it with hot water.

In every form of sparger the force which should cause it to revolve is derived from the water rushing from the small holes in the arms, and the question whether a sparger will act efficiently depends on the force thus obtained, and on the amount of friction which this force has to overcome. The friction is smallest in the first form of sparger mentioned above, and in this form but few precautions, if any, are necessary to ensure its revolving with sufficient rapidity.

In the second form, as the friction is considerably

greater, it is necessary that the power should be increased, and this may be effected by increasing the pressure of the water in the arms. In order to increase the pressure, the reservoir of the sparger is placed at some distance above the level of the top of the tun. It is made comparatively shallow, and pipes pass downwards from it, connected by means of a quarter-bend with the arms of the sparger. In this manner any amount of pressure that is necessary may be obtained by raising the reservoir and lengthening the connecting pipes.

In the third form of sparger the friction is greater than in the case of either of the other two, but, at the same time, the whole pressure of the water from its level in the hot liquor back is available. There is generally, therefore, ample power to drive it, and it has this additional advantage, that the holes in the arms are not liable to be stopped by particles of the grist, which in the other forms are likely to find their way into the reservoir, and thence into the arms.

The best constructed of this third form of sparger can be raised or lowered by means of a lever acting on a telescope tube, and this is a great advantage where there is a considerable variation in the amount of malt mashed in the same tun. This improved form of sparger was I believe first introduced by Messrs. R. Ramsden & Son.

Whatever form of sparger is used, it is of great importance to secure sufficient power to drive it by means of the water only, and I have insisted the more strongly on this rather obvious point from having known instances in some of the largest breweries in which, owing to neglect of the necessary precautions, the spargers would not revolve when actuated by the water only, and had consequently to be driven by means of belts.

Having now given a general description of the various portions of the mashing plant, I will proceed to consider a few effective combinations which I can recommend to my readers, and will then conclude this portion of my subject by describing some special forms of mashing apparatus, not much known in this country, but in common use on the Continent or in America.

Where the greatest durability and cleanliness combined with moderate cost are the objects in view, I strongly recommend the combination of a Steel's masher, and a cast iron mash tun with internal rakes. The Steel's masher may be made of iron for the sake of economy. The cast iron mash tun must be fitted with the wooden cover already described, and a cast iron false bottom perforated with numerous round holes, so as to give it the largest amount of drainage surface compatible with that form.

The internal rakes should, if possible, be driven from below, and the improved third form of sparger, with telescope tube, can then be employed. Both the sides and bottom of the cast iron mash tun must be carefully non-conducted by means of either felt or composition, and the necessary arrangements must be made for heating it by injecting free steam as already described.

Those who object to iron as a material for mash tuns, &c., and yet desire to erect an efficient plant at as low a cost as possible, may substitute copper as a material for the Steel's masher, and the false bottoms; gunmetal, as the material for the rakes; and construct the mash tun of wood, or wood lined with copper. In either of the above arrangements a good Automatic masher is an economical and fairly efficient substitute for the Steel's.

On the other hand, when the plant is to be erected

regardless of cost, the mash tun may be made of gun-metal, or copper sufficiently stout to require no wooden backing, and it can then be jacketed with an outer vessel, which if preferred may also be of copper, leaving a space between it and the sides and bottom of the mash tun, into which steam or hot water can be introduced in order to maintain and regulate the temperature of the mash.

Of course cast-iron mash tuns can also be jacketed in like manner with cast or wrought-iron jackets, and these jacketed tuns will be found very useful by those brewers who use a proportion of unmalted grain, as they allow of the mash being introduced into the tun at a low temperature, and the heat being afterwards raised by means of the jacket. I prefer filling the jacket with water rather than with steam, and raising the temperature of the water by means of a perforated steam coil, which may be of common wrought-iron steam pipe, placed at the bottom of the jacket; or the steam may be injected at a number of ports through the bottom of the jacket.

A useful adjunct for heating the mash consists of an arrangement by means of which the wort is raised from the taps into a small copper or cast-iron vessel, placed above the level of the mash tun, and provided with a steam coil and vertical strainer. The wort is best raised from the taps to this vessel by means of a centrifugal pump, as steam can then be blown direct through both pipes and pump after washing, so as to insure perfect cleanliness. The vessel is connected with the sparger, and is provided with a fine vertical strainer so as to prevent any particles of the goods getting into the sparger and choking the holes. After the mash is in

the tun, the wort can at any time be pumped to this upper vessel, heated in it, and returned to the mash through the sparger, and this operation can be continued until the heat of the mash is raised to the desired point.

A jacketed mash tun provided with internal rakes and the above arrangement appears to me to give a very perfect control over the mashing temperatures and the chemical reactions involved in the mashing process. With this apparatus the mash may be made at as low a temperature as may be thought advisable, and then equally heated to any desired degree, by means of both the jacket and the upper vessel. At the same time, provided the coil in the upper vessel is powerful enough, the action of the diastase may be controlled, or even destroyed, to any degree that may be desired. In fact by this comparatively simple arrangement pretty much the same results may be obtained as by the expensive and complicated mashing plant used in the best Continental breweries.

I have just alluded to the Continental system of mashing plant, which as adopted in the best German breweries consist of two mash tuns, and a copper, and also a centrifugal pump for transferring the mash from any one of these vessels to the others.

No 1 mash tun is a simple open tun, with very powerful internal rakes, which can be driven at a high speed. This tun is also furnished with some form of automatic masher. It is of very little consequence what masher is used, and one of the very simplest description is quite adequate to the requirements. When in use it is fixed to the bottom of the grist case, and the water supply for mashing is connected with it in the usual manner. This

water main gives off a branch to supply water to the No. 1 mash tun, and to the sparger of No. 2 tun, and to No. 1 copper.

No. 2 mash tun is also open and furnished with internal rakes, which can be driven at a moderate speed, and as these rakes are only required to stir the goods occasionally during the sparging, they need not be of any extra strength. This tun is furnished with well-fitting false bottoms, perforated with fine holes so as to form with the goods as perfect a filter as possible. A well-constructed sparger is also fitted to it, and a sufficient number of taps for drawing off the wort. These taps flow into a trough with two outlets, one of which communicates with the centrifugal pump, and the other with the No. 2 or wort boiling copper. These outlets are furnished with caps or cocks.

No. 1 copper is a shallow vessel, the depth of which is only about half its diameter. It may be heated either by the direct action of fire, or by means of steam in a jacket enclosing the whole of the bottom. This copper is furnished with a powerful chain stirrer, the chains of which when revolving sweep every portion of the surface which is exposed to heat.

The mash tuns are placed in such a position that they will command the coppers.

The centrifugal pump must be of ample power, so that it can transfer the whole mash from one vessel to another in the course of a few minutes. Its suction is connected by pipes and sluices of ample capacity, with the bottom of No. 1 mash tun, and the bottom of No. 1 copper, and its delivery is connected by pipes of an equal capacity, so that it can deliver the mash into either No. 1 or No. 2 mash tuns.

Steam pipes are connected with all the mains, so that steam can be blown through every pipe, sluice, tap, main, or pump, after they are washed. This is essential as otherwise the perfect purity of the mains could not be insured.

The mashing water is best supplied from a back heated by a steam coil in the usual way, and commanding the whole plant. The grist case is of ordinary construction.

A favourite form of mashing apparatus, and one much used in America, is that patented by Pigeon, and commonly known as the Pigeon Converter. It consists of a wrought-iron vessel with flat ends and sides, and a semi-circular bottom. This vessel is provided with a powerful paddle stirrer, instead of rakes, and is placed in a jacket or water bath. The temperature of the mash can be regulated to the greatest nicety, by heating or cooling the water in this bath. The whole constitutes a very efficient mashing apparatus, and is specially adapted for mashing a mixed grist of malt and maize; but it is equally effective with malt only, or malt mixed with any other grain. When the mash has been completed in the Pigeon apparatus, it is run into an ordinary mash tun and treated in the usual manner.

Kinder's patent converter, which combines very powerful double stirring apparatus, with steam pressure, both without and within the vessel, is capable of rapidly gelatinizing even unground rice, and is a very efficient form of converter.

It is unnecessary for me to give a fuller description of this apparatus, as plans and all particulars can be obtained by any brewer, on application to the patentee.

Ramsden's improved converter is a very simple and

effective apparatus, and to those brewers who hesitate to incur the outlay involved in the more expensive forms, it offers a cheap and efficient substitute. It consists of a tub, with a vertical shaft, driven by means of a countershaft and gearing. To the vertical shaft are affixed a beater, and screw rouser, and the heat for the conversion is supplied by means of a steam coil.

In the foregoing remarks I have omitted all mention of great numbers of inventions, designed to more perfectly carry out the mashing process. Some of these inventions have a certain amount of merit, but not it appears to me of a sufficiently marked character to render them worthy of the attention of brewers. Others are simply useless; and others again are absolutely objectionable. I have, therefore, only described those forms of apparatus, which I consider to be of real value to the brewer, and one thing I can assert most positively, and that is that with the apparatus I have described every possible modification of the mashing process can be efficiently carried out.

CHAPTER IX.

UNDERBACKS, UPPERBACKS AND COPPERS.

UNDERBACKS may be made of similar materials to those employed in the manufacture of mash tuns. In many breweries they are dispensed with altogether, especially where the boiling of the wort is effected by means of steam. Where the copper is heated by the direct action of fire, a back of some sort is essential in order to supply on the instant a sufficient amount of wort to *save* the copper, that is to say, to prevent it burning when the first wort is discharged from it.

The size of the underback in proportion to that of the mash tun varies greatly, according to the purpose which the former vessel is intended to serve ; thus, where it is only required to hold enough to save the copper, or to act as a reservoir to supply the pumps, its capacity may be very limited. Under these circumstances a simple tub or cast iron tank, without any heating arrangement, is quite sufficient. Many breweries are, however, so arranged that it is advisable to have the underback of sufficient capacity to contain the whole, or at any rate the greater portion of the second wort, and under these circumstances a capacity equal to half that

of the mash tun is the smallest that can be recommended. These large underbacks ought always to be supplemented by such heating arrangements as will enable the wort to be raised either nearly or quite to the boiling point while it remains in them. If the back be made of wood this heating power can be obtained by means of a coil of copper pipe. The heating power of this coil should be at least half that which I gave for water-heating coils, and the proportion there detailed between the length and diameter of the pipe should be observed. The coil is best laid about one inch from the bottom of the back, and should be supported loosely on gun-metal crutches. Coils made in this manner are effective and easily cleaned.

If the underback is made of cast iron, copper coils are objected to by many. Iron coils no doubt may be safely employed, but the best plan is to enclose the underback in a jacket or outer tank, leaving a space of about two inches between the two. This outer tank may be of either cast or wrought iron, and the cast iron underback itself should be jointed on the plan I have already recommended, the flanges being planed. Steam may be blown into the space between the two vessels, or it may be filled with water heated by means of free steam blown into it, either through numerous ports in the bottom of the outer vessel, or through a perforated steam coil placed between the two bottoms.

Those who object to iron and yet prefer a more durable material than wood, can make their underbacks of copper, and heat them when necessary either by means of coils or jackets.

Upperbacks placed so as to command the coppers are frequently convenient. They may be constructed of

the same materials and in the same manner as underbacks. Where an upperback is erected, the underback need only be of small dimensions, the wort being pumped from it to the upperback and heated therein as fast as it flows from the mash tun.

The importance of maintaining the temperature of the wort during its passage from the mush tun to the copper, is not generally as fully recognised as it ought to be. Practical experience in a vast number of breweries, has proved to me, that mischief always results from allowing the wort to fall in temperature after it leaves the mash tun, and before it is boiled; I therefore wish to impress on brewers the necessity of adopting some efficient plan of heating the wort, when in the under and upper backs, if it has to remain in those vessels for more than a few minutes.

Coppers and their substitutes have been made of many different forms and heated in various ways, and it is probable that every variety of wort boiling vessel has had its advocates who have believed firmly in its superior virtues. Experience has, however, caused most of these special forms of vessel to be rejected, and has greatly reduced the number of those which still merit the attention of the brewer.

I think that all varieties of wort boiling back may now be considered as obsolete, and I shall, therefore, only consider the various forms of copper properly so called, whether heated by steam or fire.

There are three principal forms of fire-heated coppers —viz., the simple open copper, such as is used in Burton and in most other ale brewing districts. The close domed copper, in which the wort is generally boiled under some pressure, and from which the steam escapes

through a pipe usually provided with a safety valve; and the domed copper with open top and pan. The close domed copper is usually also provided with a pan, but it is not so absolutely essential to its construction, as in the case of the open domed copper.

The simple open copper has some advantages over other forms, its very simplicity being not the least of these. Another advantage is that the wort is always visible to the brewer, and he can see at once whether the strong and constant ebullition which is so necessary is fully maintained. This form of copper is also easily cleaned, and its condition is always apparent at a glance. Its principal disadvantage is that it requires constant watching and attention to prevent its boiling over. In order to obviate this disadvantage the various forms of copper fountain and the boil-over-cone have been introduced. I need not describe the former contrivances which are abundantly advertised in every brewers paper. The chief objection to these fountains is the liability of the hops to choke the pipe at first starting. I generally prefer the simple cone because it is not nearly so liable to be choked by the hops, the opening in its crown being large, and there being no length of pipe for the hops to collect in. The cone should extend to within about two inches of the side of the copper, the opening in its centre should be from eighteen inches to two feet in diameter, and it must in all cases be so arranged that it cannot shift its position when in operation. This can be effected by fixing it in place by means of strong iron bars, the length of which can be adjusted for the different depths of wort in the copper, and which are so arranged that they can be easily secured.

The simpler plan, however, is to make the cone sufficiently heavy, so that when properly guided and hung it will keep itself in position by its own weight. It should be hung by means of a chain passing over a pulley, and attached at its other end to a counterpoise, so that the cone may be easily raised and lowered, and the counterpoise fixed and supported at any desired height. Other contrivances for keeping the cone in position may be adopted, but it is essential to fix it securely, for otherwise it is liable to be thrown out of the copper, in which case a heavy loss of wort is sure to occur, and the men in charge may be seriously scalded.

The close domed copper with steam escape pipe and safety valve, is still the favourite form with most porter brewers, and it is nearly always provided with a pan which acts as an upperback. I do not think that there is any objection to this form of copper when used to boil black beers, but for ales it is unsuitable; and even for black beers I cannot see that it possesses any advantages.

The domed copper with open top and pan is certainly a good form although somewhat more expensive than the simple open copper. The pan acts very effectually in preventing the copper from boiling over, the wort that boils into it returning through the open scupper holes. Just before the copper is turned out, these scupper holes are securely closed by means of valves, and enough of the second wort pumped into the pan to save the copper. The pan therefore serves the double office of boil-over-cone and upper back; the only risk with this form of copper is that the valves may not be securely closed, and that some unboiled wort may find its way into the copper while it is being turned out, and so escape boiling altogether. It is therefore essential to

keep the valves in perfect order, and to remove any hops that may have lodged on their seats before closing them.

Those brewers who prefer boiling by steam, should erect well-made steam jacketed coppers with ample heating surface, which may if necessary be supplemented by a vertical steam coil, placed inside the copper. These steam jacketed coppers, like the open fire coppers, may be fitted with either fountains or cones to prevent their boiling over. If there is a steam coil in the copper, a fountain, the bell of which stands over the coil, is a very effectual means of promoting that rapid circulation of the wort which is so essential.

Steam jacketed coppers should have at least three and a half to four inches of steam space between the jacket and copper at the bottom, diminishing to about one inch at the top.

The jackets of steam coppers should always be coated with some non-conducting material. It is often advisable to supplement the heating surface inside the jacket by a steam coil placed within the copper.

The proportion between the diameter and the depth of a copper is a most important point, and one the importance of which is too generally overlooked by English brewers, who usually have their coppers made far too deep. I may say generally that the diameter of a copper should always exceed its depth. The following are good proportions for fire coppers of various sizes :—

Total capacity in Barrels	Diameters			Depth	
	Bottom ft. in.	Throat ft. in.	Light Course ft. in.	Bottom ft. in.	Light Course ft. in.
20	4 6	5 10	6 4	2 10	1 6
40	5 6	7 5	7 10	3 2	2 7
90	7 0	9 6	10 0	4 1	3 7
140	8 0	11 4	12 0	4 0	4 5
220	9 6	13 0	13 6	5 0	5 0

About the same proportions answer well for steam jacketed coppers, making a small allowance for the bottom being dished downwards instead of upwards.

In the foregoing table I have assumed that the fire coppers are made with benches, which is the usual and by far the best and strongest construction. Coppers with benches are also more easily set than those without, and the brickwork closing in just beneath, and in contact with the bench, effectually stops the fire from ascending higher on the sides of the copper. The copperman consequently knows that as soon as the wort is up to the bench, he can safely fire up, close the fire door and open the damper.

In some breweries very broad, shallow coppers are used with a diameter equal to double their depth, and if as large an amount of evaporation as possible is desired in the shortest space of time, these coppers are, no doubt, advantageous. These shallow coppers are much used in Continental breweries, and for heating the mash in the decoction process they have great advantages.

In setting fire coppers all the flues should be of ample size: small ports and cutting draughts should be avoided. The dead plate should be outside the lag of the copper, and the bars extend from it to rather beyond the centre. The bridge at the back of the bars should extend upwards to within about nine inches to fifteen inches of the bottom of the copper. A pit or combustion chamber should be formed behind the bridge, and the port or ports communicating with the flue, or flues should be of ample size. A single draught is certainly best for all except the largest coppers, which latter may be set with a split draught and double flues.

All flues in contact with the fire must be lined with

firebrick. The soot doors and manholes should be of ample size for cleaning the flues.

The amount of copper capacity required in a brewery depends to a great extent on the method of boiling. Some brewers prefer to boil the wort of a whole brewing at once, others boil the worts at twice, and some make three boilings. I may say generally that the capacity of the coppers should be sufficient but not excessive, and there is a great advantage in having that capacity divided between two or more coppers, rather than having one large one, in fact, every brewery should have at least two wort coppers, and these may be of different sizes so as to suit the various lengths of beer brewed.

In large breweries I much prefer the Burton plan of having a number of comparatively small coppers, of a working capacity of from 80 to 100 barrels each. They are much more manageable, and do not colour the worts so much as large coppers, and there is the further great advantage, that any one of them can be repaired without interfering with the work of the brewery.

When a number of small coppers are used the underback may be of the smallest size, as there is always a copper ready to receive the wort.

CHAPTER X.

HOPBACKS, HOP PRESSES, COOLERS, AND REFRIGERATORS.

HOPBACKS may be made of wood, sheet copper, or cast-iron. Those brewers who object to the use of iron and are not prepared to invest a large amount in copper utensils, can have their hopbacks made of wood, with false bottoms of sheet copper perforated with numerous holes, and well supported on strong wooden bearers. Those on the other hand who do not object to erect costly plant, provided it is correspondingly durable, can have copper hopbacks with slotted gun metal false bottoms.

I myself, however, can see no objection to cast-iron hopbacks with cast-iron bottoms, either slotted or perforated, for no material can be more cleanly or durable. The plates of which the hopback is formed must be made of a quality of cast-iron which will not crack on that sudden application of heat, which occurs each time the boiling wort is turned out of the copper. The tannin of the hops coats the iron with a perfectly insoluble and adherent film, so that after the hopback has been used once or twice, there is not the slightest chance of any iron being dissolved by the wort, and it

is then as perfect a utensil as can be desired, whether it is used for pale ales, mild ales, or black beers.

Wooden hopbacks with cast-iron bottoms are of course the cheapest of all constructions, and answer well as long as the wood continues sound.

The false bottoms of hopbacks of all descriptions should be provided with ample drainage surface. It is not necessary or even advisable to have the slits or perforations so small as in the case of mash tun bottoms. The hops themselves form a perfect filter for the wort as soon as they have settled down, and all that is necessary is to have plates that will support them while the wort filters through. On the other hand the plates should be so open as to allow the air to escape freely and at once, otherwise it will, by escaping slowly and at intervals, keep the worts stirred up and prevent the sediment from depositing.

I think that the best false bottom for a hopback is formed of coarsely slotted plates with some plates with finer perforations placed just where the wort impinges, as it flows from the copper.

Angle plates should be fixed across one or more of the corners of all hopbacks, so as to facilitate the escape of the air; and these plates also prevent any suck from the pump disturbing the hops when its suction main is connected direct to the hopback. The plates should be supported so as to leave a space of about one and a half inches to two inches between them and the bottom.

As regards the best proportions for hopbacks, it is advisable that they should not much exceed three feet in depth, and they must have ample capacity to contain the whole contents of the copper or coppers which are at any time to be discharged into them.

Various contrivances have been introduced to enable the brewer to extract the wort which still adheres to the hops after they have been drained in the hopback. These contrivances may be classed under the heads of screw presses, hydraulic presses, and arrangements for washing the hops by means of some form of sparger.

Screw presses are cheap and moderately effective, they should be of sufficient size to contain all the hops from one boiling, and they may be worked either by hand or by power.

Hydraulic presses are very expensive, and although they extract a little more wort than the screw presses I doubt whether this extra wort would not be generally better thrown away with the hops. In very large breweries, however, and where much strong ale is brewed, or where the hops are only boiled once, the hydraulic press, driven by steam power, has manifest advantages over any form of screw press.

Various other forms of press have been introduced, but as they generally crush the hop seeds, the wort they extract is useless, and their only value is to dry the hops so that they may be mixed and burnt with the coals.

If the plan of sparging the hops is adopted, the water may be applied by means of an ordinary sparger if the hopback is circular, or if, as in some breweries, a small supplimentary tub is used. Square or oblong hopbacks require a special sparger made to traverse to and fro along the the top of the back.

In small breweries the simplest plan is to apply the water by means of a hose and spray jet. A few barrels of boiling water applied in this simple way, and then a good squeeze in a common screw press, is quite sufficient

to extract all the wort of any practical value that remains in the hops after they have been drained.

The high price of hops during the season of 1883-4 compelled brewers to study economy in their use, and now few if any brewers continue the extravagant practice of throwing away hops which have been only boiled once in a strong first wort; methods, therefore, of returning hops to the copper are now considered to be of more importance than formerly. For this purpose every brewery should be provided with a good steam hoist. In small breweries baskets raised by means of a common sack hoist answer well, but in large breweries waggons running on tramways and raised by means of a powerful steam hoist, or still better by hydraulic power, should always be provided.

Coolers may be constructed of the same materials as hopbacks, and the same remarks as to materials apply to them. Owing to their large area they are generally constructed of wood for the sake of economy, but there are very strong objections to the use of that material. It answers well while the wood is sound, provided the most scrupulous cleanliness is observed, with daily scaldings with boiling water, and frequent applications of bisulphite of lime solution; but the wood in a few years decays in places, and then commences that series of difficulties and disasters which have been so often traced to these utensils.

It should always be remembered when considering this part of my subject, that coolers serve four principal purposes, viz.: first the aeration of the hot wort which has already been partially effected in the copper and hopback; secondly the aeration of the cool wort, which is now far better accomplished by passing it in a thin

film over a vertical refrigerator; thirdly the deposition of the sedimentary matters from the wort; and lastly the cooling of the wort, for which purpose a good refrigerator is more convenient and effective.

Coolers are now therefore only really required for completing the aeration of the hot wort, and for allowing the wort to deposit its sedimentary matters. When therefore the supply of refrigerating water is abundant, and vertical refrigerators can be used, the dimensions of the coolers may be greatly reduced, especially if the aeration of the hot wort is assisted by pumping it from the hopback to the coolers.

These small coolers which are I consider still essential, or at any rate most useful, may be constructed of cast iron, or even copper, without any very excessive expenditure of capital. They may be made about eighteen inches deep, and of the same capacity as I have recommended for the hopback.

Where horizontal or close refrigerators are used, and especially where the wort is not pumped from the time it leaves the copper until it arrives at the refrigerators, shallow coolers of large area and placed in an airy situation are almost essential to the success of the brewing operations, and particularly to the rapid and spontaneous fining of the beers. These large coolers I much prefer to make of either cast iron or copper. Cast iron may be used with perfect safety, and will not affect the most delicate pale ales, provided every speck of rust is removed as soon as it appears. The best plan with these iron coolers is to scour them with sand at regular intervals, and also when from any cause rust has made its appearance. Then as soon as they are well scoured with the sand, and the latter is washed off, apply

a solution of tannin, which will immediately coat the iron with the insoluble film before mentioned, and render the coolers again sure not to injure the palest worts.

Where water is scarce, and cooler room ample, the old fashioned fans are still sometimes used, and might, I think, be more extensively employed with advantage.

Refrigerators have for many years offered a large and remunerative field for the exercise of the inventive faculties of brewers' engineers, the result being that we now have almost every conceivable form of this most essential portion of the brewery plant.

Many of these forms, although fairly effective, have become practically obsolete; those brewers who have them continue to use them until they are worn out, and then substitute more efficient varieties.

This process of natural selection and elimination has proceeded so far that I do not think I need occupy space and time in even alluding to a vast number of refrigerators, which have enjoyed a certain reputation in their day, but which probably no brewer would now think of erecting. I shall confine my remarks, therefore, to the principal types, and to what are now generally allowed to be the best exemplars of each.

I think I may class all refrigerators under three heads, viz.: those in which the wort flows in a body over the outside of pipes placed horizontally, with the water passing in the opposite direction to the wort and through the inside of the pipes. Secondly, those in which the wort flows in a film over the outside of pipes placed vertically, the water flowing inside and in the opposite direction to the worts: and thirdly, those in which the wort flows through the pipes, and the water outside them.

Most of the earlier forms of refrigerators belonged to the first or last of these classes, but owing to no effective precautions being taken to keep the inside of the pipes of the latter clean, these early close refrigerators led to serious disasters, and were soon abandoned in favour of those of the first class, the simpler and rougher forms of which were almost exclusively used by brewers for many years. Many of these old horizontal refrigerators are still in existence, but they are now rapidly disappearing, and the form known as the Moreton Refrigerator is now almost the only horizontal refrigerator that brewers think of erecting. The Moreton Refrigerator is so well known, that a minute description of it would be mere waste of time, I will only remark, therefore, that its great surface of flat pipes, and the method in which they are arranged, makes this refrigerator a very powerful and effective one, but on the other hand, its construction renders it difficult to keep it perfectly clean. Great care and the constant use of the brush, together with a frequent wash with caustic soda, suffices to keep this refrigerator in fairly good order, but if anybody was to invent one that combined the efficiency of the Moreton, with a construction that could be easily cleaned, he would confer a boon on brewers.

The imperfect character of even the best horizontal refrigerators, has induced an immense number of brewers to supply themselves with various forms of vertical refrigerator, and the almost perfect construction of some of the best of these, bids fair, in a few years, to drive the horizontal class out of the market.

Vertical refrigerators are made with either round pipes, flat pipes, or on the Lawrence construction of corrugated sheets.

Of these the refrigerators with round pipes are the least effective, and are almost obsolete. All good vertical refrigerators are now made either of the Bandelot form with flat pipes or of the construction invented by Lawrence.

The improved form of Bandelot patented by Turrell, and of which Messrs. L. Lamsier & Son are the makers, is I think, taking all things into consideration, the most perfect refrigerator which has been introduced up to the present time. The improved Lawrence refrigerator, is equally effective with the above, but is more expensive and not of such a strong construction. The Lawrence will not stand so high a pressure as the improved Bandelot, and is therefore not so well adapted for those cases in which the water has to be pumped through the refrigerator against a considerable head.

All the best forms of vertical refrigerator possess the following advantages, viz:—

They effect the perfect aeration of the wort and therefore no large coolers are required.

They are easily cleaned without much labour or loss of time and any carelessness in regard to the cleaning can be detected at a glance.

They effect a great economy in the quantity of cooling water required, for with an improved Bandelot or a Lawrence less than two barrels of water is required to cool one barrel of wort, whereas the best horizontal refrigerators require at least double that proportion of water.

Every Brewer who erects a horizontal refrigerator of even the best construction throws away all the above advantages. Even in those breweries not originally adapted for vertical refrigerators, it is far cheaper to go

to the necessary outlay of a centrifugal pump and a small back commanding the vertical, rather than to erect one of the much more expensive horizontal forms and the large cooler they render necessary. In fact an improved Baudelot with pump and back can be erected complete for about half the cost of a Moreton with coolers of sufficient size to make it effective.

The last form of refrigerator that I have to notice is that in which the wort flows inside instead of outside the pipes.

The two best refrigerators of this description are Ashby's and Riley's. Both of these have done good work, and if for any reason or purpose a brewer wishes to erect a refrigerator of this description, his choice lies between the two. For all ordinary purposes, however, this class of refrigerator has become obsolete.

CHAPTER XI.

FERMENTING TUNS AND OTHER FERMENTING VESSELS.

WHEN the wort has been cooled, and is ready to be subjected to the process of fermentation, the Inland Revenue Act of 1880 directs that it shall be run first into a vessel or vessels, marked as the collecting vessels, and that it shall remain in such vessel or vessels for not less than twelve hours, or until the bulk and gravity of the wort has been ascertained by the excise officer.

These collecting vessels may be either the ordinary fermenting tuns or special vessels, but in either case as long as the beer remains in the collecting vessel, it is subject to samples being taken from it at frequent intervals by the officers of excise.

Owing to the above regulations, many brewers think that it is advisable to have a special collecting vessel, and I am inclined to agree with them, in breweries where the skimming system is adopted. It is decidedly annoying to have the head of the beer constantly disturbed, and if the officer takes the samples carelessly, just as it is ready for racking, the beer may be injured. Such preventible causes of friction between the brewer and the officers should certainly be avoided.

Special collecting vessels are best made large enough to contain a whole brewing, and one vessel for each brewing that is to be made in the twenty-four hours, is sufficient. One advantage in the use of these collecting vessels is, that most of the sedimentary matters which may have run down with the wort, are either thrown up with the first head, or are deposited during the twelve or more hours that the beer remains in the said vessels. In either case, these sedimentary matters remain behind when the beer is run to the fermenting tuns, and a cleaner yeast is thus obtained.

Collecting vessels are made of the same materials as fermenting tuns, and like them may be either square or round. They differ from fermenting tuns in two particulars, for in the first place they may be made of any convenient depth, and in the second place they may be filled within about six inches of the top, as the beer is not to remain in them long enough for the head to rise to any great height. They should be provided with moveable covers for use in cold weather.

I may here mention a special collecting vessel with which all breweries should be provided, if it is intended to "syrup" or "wort" any of the beers. This operation can only be legally performed with syrup or wort, which has first been placed in a collecting vessel, so that the duty may be charged upon it. As a special syrup or wort is generally used, a special collecting vessel must be provided, and as all fermentation has to be avoided, wood is a very bad material, owing to its porosity and consequent liability to form a nidus for the organisms of fermentation.

Slate is often used, but by far the best material for these small special collecting vessels is the salt glazed

pottery so much employed for chemical apparatus, and commonly known as Lambeth pottery. The vessels known as mixing pans, are the most convenient, they are made of a capacity of twenty gallons and upwards, and are provided with covers of the same ware. They can be safely washed with boiling water, and as the glaze is perfectly impervious, the greatest security against fermentation is obtained by their use.

To return now to the fermenting plant. Although the large collecting vessels I have mentioned have been adopted in a few breweries, the more usual plan is to use the fermenting tuns themselves as collecting vessels.

The same materials and methods of construction are equally applicable for both classes of vessel, and I will now proceed to their consideration, taking the materials first.

The materials generally used in the construction of fermenting tuns are wood, slate, and stone. Experiments have been made with glass, and with glazed bricks and tiles laid in cement; these experiments however have not been successful, and have consequently been abandoned.

Fermenting tuns have also been lined with lead, and with copper; but the danger of a poisonous amount of those metals being dissolved by the beer appears to me to constitute a most serious objection to such linings. The use of lead for such a purpose must certainly be most emphatically condemned. Copper is by no means so dangerous a material, and providing it is scoured every time just before filling, there would I think be very little risk in its use. Experiments in this direction may be made with advantage, as it is evident that if we could conduct our fermentations in vessels lined with an absolutely non-porous material like copper, and one that

could at the same time be raised to the boiling point without risk of damage, by means of steam or boiling water, we should have secured ourselves, at one point at any rate, against the intrusion of the ferments of disease.

Cast iron is also used in the large Irish porter breweries as a material for their special cleansing vessels ; but even for black beers I am not aware that it has been yet used as a material for the primary fermenting vessels. I see no reason however why cast iron coated with an adherent and impervious varnish, should not be used in the construction of most forms of fermenting vessel.

Returning to the consideration of the materials in general use for fermenting vessels ; wood claims the first place, as being that used in the vast majority of breweries.

The woods best adapted for this purpose are English oak, foreign oak, and the firs from Dantzic, Christiana and Archangel, &c.

Of these English oak is the most durable. Vessels constructed of it have also the advantage of being easily seasoned, so that they will not impart any flavour to the beer. All that is required is to fill them once or twice with boiling water before using them. Vessels constructed of foreign oak can be seasoned in the same manner, but are not nearly so durable. Both English and foreign oak are, however, expensive materials, and consequently the above named firs are generally preferred. When these latter woods are used, means must be taken to remove their resinous flavour, which would otherwise be imparted to the beer.

In order to effect this object the vessels should first be thoroughly scalded by filling them with boiling water ; on the following day the water is run out, and they are

whitewashed with a mixture of two pounds and a half of chloride of lime in a gallon of water. After this has remained on for twenty-four hours, a second wash is applied, composed of one part of common hydrochloric acid (spirits of salts) to four of water. Twelve or fourteen hours afterwards the vessel is thoroughly washed several times with boiling water and finally with the ordinary bisulphite of lime solution, which destroys any smell of chlorine which may still remain. Fir vessels which have been treated as above may be used at once for ales without risk of imparting any flavour.

I must caution brewers who use oak vessels, against the excessive use of quicklime and especially against leaving it long in contact with the wood. Quicklime does not injure resinous woods, because it forms an insoluble combination with the resin, but the combination of lime with the astringent juices of oak, is perfectly soluble in water, and consequently all the nature is soon taken out of even the hardest oak, by the continued action of limewater. The wood then becomes soft and porous and rapidly decays. I know an instance in which a set of fermenting tuns, made of the very best English oak, were rendered utterly useless in ten years by being kept full of lime and water during the summer months, while the brewing operations were partially suspended.

In the construction of wooden rounds and squares, the first consideration, whichever form is adopted, is that the vessel shall not only be water-tight, but also that its internal surface shall present no cracks or crevices in which yeast and other matters may accumulate. Every back maker of good standing is sufficiently alive to the necessity of making tight work: but in their desire to give it a good and finished appearance on the outside

they are too apt to pay more attention to the perfection of the joints externally than internally, whereas the brewer is chiefly concerned to obtain a perfectly continuous internal surface, even at some sacrifice of external appearance. Some back makers assume that a perfect vat is one in which each plank or stave is jointed so as to come perfectly in contact through its whole thickness with those adjacent to it. For several reasons, however, I cannot coincide in this view; in the first place, such theoretical perfection is never really attained; and in the second, I question whether, even if attainable, it is desirable. In an old vat, if taken to pieces, it will nearly always be found that the wood shows most signs of decay in those places where the adjacent surfaces have been in contact throughout their whole thickness; whereas those parts are nearly always the soundest where, while the joint is perfect internally, it is slightly open externally. Again, as the different parts of a vat are held together with a certain definite pressure by means of the hoops or bolts, and as the same amount of pressure will make a tighter joint if distributed over only a small surface than over a large one, it is evident that the tightest work will be made by concentrating the pressure where it is most needed, that is to say, internally; I consider, therefore, that the most perfect vat is one in which, while the joint is absolutely close from end to end on the inside, and for a small portion of the thickness adjacent to it, it is at the same time slightly open, or I should rather say, not so close externally. This rule applies equally to both square and round work, and to the bottom as well as the sides.

All the wood used in the construction of fermenting tuns must, of course, be absolutely free from dead knots,

sap wood, or any unsound or soft portions. If a plank or stave is otherwise sound, it need not, however, be condemned because of one or two dead knots, as these can be entirely bored out, and the holes plugged with a piece of sound wood.

As regards the seasoning of green timber, its evenness is of even greater importance than its being carried to the highest point of dryness; it is necessary therefore, that the timber, before it is used, should have been standing for some time under cover, and arranged on racks, or piled with narrow strips of wood placed between each plank or stave, so as to allow the air to circulate freely over their surfaces.

In cases in which naturally seasoned timber could not be obtained, I have known instances in which excellent rounds and squares have been made of wood artificially seasoned by means of either hot air or steam. In seasoning by means of hot air the planks must be shifted several times, so as to ensure that all parts of them are equally dried. When steam is employed the planks must be laid on edge, and quite separate from one another, immediately after they are removed from the steaming-chamber, and they must remain for some time in this position. Artificial seasoning is undoubtedly very effective, but to ensure good results every detail of the process must be intelligently superintended.

In making a round vat, after suitable wood has been obtained, the first thing is to arrange it so that it may be cut into staves with the least loss, and so as to take advantage of the taper of the staves to remove sap wood. There is not much difficulty in doing this in the case of deal and pine, but with English oak, owing to its irregular growth, great judgment is required. Undoubtedly it is

preferable to form all the staves with an equal taper, and for wooden mash tuns, or other open vats subjected to heat, this is almost essential; but for covered vats, of no great depth, and not subjected to heat, staves differently tapered may be employed. In open vats every stave ought to have some taper in the same direction.

As to the amount of cone necessary to allow of driving the hoops, the usual allowance is to make the smaller end of the vat less than the other in proportion of one inch for every foot of depth. The sides of the vat must not however be a true cone, but must have a slight bulge outwards, to prevent the staves from giving inwards when the hoops are driven tight; this is called the "quarter" or "shoulder."

Vats without cone are sometimes made, and hooped with screw-clamped hoops; in this case the strap of each of the clamps must be made of ample length—nine inches to a foot at least—and curved so as to exactly fit the round of the vat. The clamp on one side should be riveted to the hoop at some distance from its end, and the clamp on the other end of the hoop should coincide, so that when the hoop is applied to the vat this latter clamp slides over the projecting end of the hoop, and does not bite into the wood. Clamped hoops are in all cases weaker than those which are riveted and applied to the vat by driving; the use of clamped hoops should therefore be avoided as much as possible.

As regards the number of hoops, the usual practice is to use an extra strong one for the chine, and one above this for every foot of height of the vat. A little more than one inch of width of hoop is the usual allowance for every four feet diameter of vat, and one dowel is generally allowed for every second hoop.

The chines should be cut well up from the end of the stave—three inches is a good distance—and the chine itself may be cut the full thickness of the bottom, or, if for some reason it is not desirable to have much of the stave below the bottom, the bottom may be bevelled off upwards, but leaving it flat inside.

In squares the different parts are held together by means of bolts passed through holes bored in the thickness of the wood. The planks are first sorted into widths, and then cut into the lengths necessary to form the bottom, sides and ends. The planks are then dressed, and the edges roughly jointed; lines are then drawn across them to give the direction of the holes, which are bored either with a worm augur, or, what is more convenient, with a boring machine; a crease is then driven into the edges of the wood with a caulking tool the whole length of each plank; this caulking tool should be from one-eighth to three-sixteenths of an inch thick on its rounded edge, and two to three inches wide. This caulking tool should be applied quarter inch from the inside face of the plank and it is a very good plan to have a gauge fixed to the side of the tool, so as to keep it straight, and at an equal distance from the inside face of the plank.

Some back makers put this crease, or several creases, along the middle of the edge of the plank, and knock in the wood round each of the bolt holes; but I think that one narrow crease in a straight line between the bolt holes and the inside face of the plank is the most satisfactory, as the joint cannot be too near that face.

When these creases have been well driven in to a depth of nearly one-eighth of an inch, the planks are planed down to nearly the level of the bottom of the

crease, and at the same time most carefully jointed to the next plank for about one half an inch from the inner face, leaving the rest of the edge the least degree bevelled off.

The bolts, which must be long enough to pass right through the bottom, for the sides and ends, are best made with T heads no thicker than the bolts themselves, the heads being sunk into morticed holes, which are afterwards plugged, and then driven through the holes, and screwed up, with wooden washers under the nuts; the sides are then rebated for the end, and the end squared and fitted to the rebates, and the whole bolted together with a little thick white lead paint. The sides are held to the ends by means either of backnails, or by bolts passing externally to the ends, and screwed up against iron plates placed against the sides.

Squares made on this plan do not require to be made tight by means of any caulking material. If sufficient care has been taken in making the joints on the above plan; the swelling of the grain of the wood which has been driven in renders the joint absolutely tight almost immediately the square is filled, even if it has been left dry and empty for a considerable time.

Mr. W. Ramsden has recently patented a plan of making squares with rounded angles and corners which I consider to be a very valuable improvement. This does not increase the cost of the vessel, and certainly renders it much easier to keep it perfectly clean; in fact squares constructed on this plan are more easily cleaned even than rounds.

Having now described pretty fully the best methods of constructing fermenting tuns of wood, slate is the next material that claims our attention.

It is now some forty or fifty years since large slabs of slate first came into general use for many purposes, and especially for the construction of tanks. The imperishable and impervious nature of slate early recommended it to the attention of brewers, especially for the construction of fermenting and settling squares. These are put together in much the same manner as those constructed of wood, that is to say, the ends are rebated into the sides, and both into the bottom of the square. The whole is held together by bolts, and the joints made tight by means of a putty composed of white and red lead and boiled oil. In large squares the sides, ends, and bottoms have each to be built up of several slabs, which are halved together and secured with screws. The fewer there are of these joints the better, and therefore preference should be given to the largest size slabs, provided they are otherwise of good quality.

There are two objections to slate squares, one is that being an excellent conductor of heat the beer is more liable to be affected by the external temperature than when wood is the material used. This objection may be overcome by the use of some sort of jacket or non-conducting composition, but this of course adds materially to the expense.

The other objection to slate, is the difficulty of keeping its surface free from impurities. Slate will not stand hot water at even a good many degrees below the boiling point, without risk of fracture; it is therefore impossible to destroy the vitality of any disease germs adhering to it by means of heat. Antiseptics and cold washes have therefore to be resorted to, and these must be of a nature not to attack or injure the surface.

Sulphurous acid and acid sulphites act injuriously on

some varieties, salicylic acid on the other hand is very expensive. Neutral sulphite of lime, applied as a white-wash, is probably one of the best antiseptics that can be applied to slate, and has the advantage of being cheap.

Antiseptics however are not of themselves sufficient, for it is absolutely necessary to remove any fur and scale that may form on or adhere to the surface of the slate. This can be done mechanically by constant polishing with soft brick; but the expense of the labour required is often considerable. One of the cheapest and best cold washes for softening and removing fur and scale is caustic potash solution, and caustic soda is nearly, though not quite as effective. These solutions should be applied with a mop made of cotton or linen rags, and the workmen must be cautioned not to allow any of the solution to adhere to their skin or clothes.

The above objections to slate apply chiefly when it is used for constructing ordinary fermenting squares. As a material for settling squares it leaves little to be desired, for the beer does not remain long enough in these latter vessels to form any large amount of scale or adherent deposit on their surface. All that is necessary is to thoroughly clean the slate settling squares directly they are empty, and to give them an occasional wash with antiseptics and caustic potash or soda.

Slate is also well adapted for the construction of yeast storage vessels and has been largely used for this purpose. These yeast vessels should be about eighteen inches deep and constructed with a double bottom. In the space between the two bottoms cold water is made to circulate in a zigzag direction by means of slatts of slate touching the opposite sides alternately. Bolts are passed through the two bottoms and the slatts at frequent intervals, so as

to hold them firmly together, and thus enable the bottoms to resist the slight but necessary pressure.

These bolts should be of gun metal and their heads recessed into the slate and puttied in, so as to present a smooth and uniform surface internally. Internal bolts should be of course avoided as far as possible, but when they are necessary the above precautions should be adopted.

These slate yeast vessels may also be advantageously furnished with moveable attemperators of tinned copper pipe fixed in wooden frames. These are suspended in the yeast when first skimmed off the fermenting tuns into the yeast vessels, and assist in keeping it cool.

A short pipe of three or four inches diameter passes through both bottoms of the yeast vessel, and is furnished with a plug which allows the beer and yeast to be easily withdrawn.

Slate is also coming daily more into use for the construction of the well known Yorkshire squares, hitherto called stone squares, owing to their having been always constructed of slabs of stone until within the last few years. For the construction of these squares, slate possesses several advantages over stone, for it is both a better conductor of heat, and its surface is also more impervious and durable, and takes a better polish, so that it can be more easily kept clean. The heat conducting powers of slate, although a disadvantage in the case of ordinary squares, is a positive advantage in the water-jacketed vessels I am speaking of, as it facilitates the regulation of the temperature of their contents.

The use of stone as a material for fermenting vessels is almost entirely confined to the above named Yorkshire squares which are constructed as follows :

Each of these stone squares consists of a partially-covered lower square containing the beer, surmounted by an open trough or upper square, into which the yeast works; the lower square is also surrounded on its four sides by an outer vessel or jacket. Arrangements are made for keeping this jacket filled with water at a regulated temperature, and by this means the temperature of the beer during fermentation can be effectively controlled.

The square is usually built of heavy slabs of a peculiarly hard and impervious stone; these can only be procured in a few localities of sufficiently large dimensions and with the smooth surface essential, for with a cracked or uneven surface perfect cleanliness would be impracticable. The scarcity of stone of the right quality, and the great cost of transporting such heavy masses to distant localities, has hitherto tended to limit the adoption of the system. Owing to the great weight of these squares, solid brick piers, built on a thoroughly sound foundation, are absolutely necessary to support them. On these piers is laid the bottom, which must be some inches larger than the outside measurement of the jacket. The sides of the square itself are then erected on the bottom, all the joints being well fitted and cemented together. The weight of the stone slabs is so great that it alone is sufficient to keep the sides firmly fixed on the bottom; but bolts are passed through the sides externally to keep them together, as in wooden squares. The four slabs forming the jacket, which must be large enough to allow a space of some two inches between them and the sides of the square, are now erected on the bottom in the same manner. The sides of the jacket are two or three inches less in depth than those of the square, so as to allow the water used for attemperation to flow freely away over

their upper edge. The covering slab of the square is now fixed and cemented to it. This cover has two holes in it: the larger one, which is about 18 in. diameter, is in the centre of the slab, and is surrounded by a ring of stone about five or six inches high, forming a sort of lip or neck to the square, which has somewhat the shape of a bottle; the smaller hole is about two inches in diameter, and is provided with a valve, and also a tube called the organ pipe, which reaches to near the bottom of the lower square; this hole is usually placed about midway between the central aperture and the side.

The yeast-trough or upper square is formed of four stones, erected on and cemented to the covering slab, which acts as its bottom; it is of the same area as the square itself, and about two feet to thirty inches deep.

I can see no reason why similar jacketed squares should not be constructed of several other materials or combinations of material besides stone and slate. Thus slate might be used for all those portions which come in contact with the yeast and beer, while the outer jackets might be constructed of wood, or of cast iron coated with felt. For black beers I can see no reason why the whole of the vessels should not be constructed of cast iron.

The Yorkshire stone square system is an excellent one for many classes of malt liquor, and I am sure it could be extended with advantage to many localities where it has not hitherto been introduced.

In working this system a good hand pump is required. This pump, which is generally of the simplest description, should be made of tinned copper. In some large breweries these pumps are fixed and worked by power.

I will return now to the consideration of the ordinary wooden fermenting tuns. These should in all cases be

made deep enough to contain not only the beer, but the head which rises on it during fermentation. Formerly most fermenting tuns were only made deep enough to retain the beer, and a structure of thin boards, called yeast boarding was erected on the top of the squares to retain the yeast. The great objection to this plan is that the thin boards can never be so closely jointed, as to prevent collections of stale yeast and other impurities from being retained in the cracks, thus involving the constant risk of contaminating the yeast and beer. I therefore object most strongly to this construction. Where however yeast boards have to be used in connection with old plant, they must always be made moveable, so that they can be taken down every time the tun is emptied, and thoroughly scrubbed and scalded.

I object to all fixed covers to fermenting tuns. Where covers are needed they should be moveable, being made either so that they can be lifted entirely off, or else in two sections, hinged to a bar or bars, which may be central or otherwise. These latter covers should be raised by means of ropes passing over pulleys, with counterpoises to enable the covers to be lifted easily.

Fermenting tuns of the same general form are adapted for either the cleansing or the skimming systems of fermentation, but the best proportions, and the fittings required, differ somewhat in the two cases.

The fermenting tuns in a cleansing plant may be of the simplest possible construction. They must be deep enough to hold both the beer and the head that rises on it, but the exact proportions are of little consequence, and may be varied according to circumstances. The only fittings required for these tuns, are a large full-way cock to draw off the beer for cleansing, and a screw plug

or cock for washing out. Even this latter is often dispensed with, and the one full-way cock used for all purposes.

For summer brewing attemperators in these squares are useful, but provided there are attemperators in the cleansing vessels, they are by no means essential.

When fermenting tuns are to be worked on the skimming system, both the dimensions and fittings are of great importance, for tuns of more than a certain depth will not give good results, and the regulation of the temperature of the fermenting beer, which is so essential, depends entirely on the attemperators.

As regards proportional dimensions, I find it a safe rule, never to have a greater depth of beer than four feet, whatever may be the capacity of the tun. Above this four feet the tun should extend for from twenty-four to thirty inches, to allow room for the head during fermentation.

In order to allow free access to the tun when skimming, rousing, &c., a working way at least thirty inches wide, should be cut out of the tun, from its top downwards to within a few inches of the highest level the beer is to stand at. This working way is fitted with boards, about six inches wide, and sliding in grooves. These boards serve to retain the yeast as the head rises.

The fittings required on the skimming system are attemperators, skimming apparatus, rousers, cocks for drawing off the beer, and screw plugs or cocks for washing out.

The attemperators should be of ample power and the pipes should be so fixed in the tun as to leave ample room for cleaning round them, and for scrubbing the sides of the tun behind the pipes. The first coil of pipe

should be so placed, that it will be only a few inches below the surface of the beer, and there should be a space of about six to eight inches between the pipes.

The pipes are best supported on gun metal brackets, screwed to the sides of the tun, and each coil of pipe should be its own diameter nearer the centre of the tun than the one above it, the coils being about eight inches apart. The water inlet pipe may enter the tun at any convenient place, and must deliver the water into the extreme end of the upper coil. The outlet must take the water away from the extreme end of the lowest coil, and must then rise to a little above the level of the uppermost coil, so as to keep all the coils full of water. The regulating cock is best fitted to the inlet pipe, and must be so placed that the brewer, when regulating the flow of water by means of it, can see the amount that is flowing from the outlet into the waste funnel.

I have so far considered those attemperators which are fixtures in the fermenting tuns, and formed of simple coils of pipe arranged vertically. These pipes may be either round or flattened, but I do not think there is any advantage in the latter form over the common round pipes.

Besides these simple fixed attemperators there are some special forms for which advantages are claimed, such as the multitubular attemperator, patented by Clinch, and which is combined with a screw rouser and bellows aerator. This arrangement is effective, but excessively troublesome to keep clean, owing to the enormous number of small tubes which have to be brushed out every time the tun is cleaned. If one of these tubes is missed there is a liability of contamination from the stale yeast adhering to its inside.

Besides the fixed attemperators portable ones are occasionally used. They consist of horizontal coils of pipe fixed to a wooden frame, and are sometimes useful in small tuns, and where an occasional slight attemperation is required. The coil of pipe and the frame to which it is fixed, must be so arranged that the whole can be easily cleaned, and all adherent yeast removed. When in use these portable attemperators are suspended in the fermenting tun, and connected with the water supply and waste, by means of India rubber tubes.

The amount of cooling surface required, in order to give full control over the fermentation, when working on the skimming system, is about 55 square inches to the barrel of beer. The best sizes of tinned copper pipe to use are—one and a half inches diameter for tuns of 50 barrels and upwards, and one inch pipe for smaller tuns. The length of the pipe required will, therefore, be one foot of one and a half inch pipe, or one and a half feet of one inch pipe per barrel.

All attemperators should be fed with water from the tank erected in the fermenting room at such a height as to give about eight or ten feet of pressure. I have already described in Chapter IV. the best arrangement of mains to insure a constant supply of water to this attemperating tank at the lowest possible temperature.

Skimming may be performed by hand, with a skimmer like that used to separate the cream from the milk, only very much larger. Various mechanical contrivances have been devised to facilitate the operation.

One of the most ordinary forms of skimming apparatus is the "parachute," which it so well known to brewers that a minute description is unnecessary. Parachutes are made of various forms, the commonest of which is that

with the funnel shaped top. A better form for large rounds, is that with the head shaped as a narrow segment of the circle of the tun. In this latter form the pipe is placed eccentrically, the head extending from the circumference to the centre of the tun. A skimming board, made to revolve on a rod in the centre of the tun, quickly pushes the yeast before it into this form of parachute. Squares are sometimes fitted with parachutes, with a trough-like head, close to, and running the whole length of one side. A skimming board fixed on a travelling carriage, or on a simple long handle, can be drawn from one side of the tun to the other, and pushes the yeast into this trough. The trough is sometimes made less than half the length of the side of the tun. Whatever form of parachute is adopted, its pipe should be of ample size. The smallest parachute pipe should not be less than four inches in diameter, and for large parachutes pipes of six inches are advisable.

A system of skimming by means of a pump delivering the yeast into bags, was patented by my brother in January, 1884. I have since that time introduced this system into many breweries, and with the most satisfactory results. The three great advantages of this system are: first, that all yeast troughs and settling vessels are dispensed with; secondly, that the beer which is skimmed off with the yeast is immediately returned to the gyles without loss or deterioration from yeast bite; and, thirdly, that the yeast is at once obtained in a suitable condition for pitching.

Messrs. R. Ramsden & Son are the sole makers of this apparatus, which may be used either with or without a parachute. The latter is however rendered quite superfluous by this new system, which combines cheapness of

original construction with perfection of working. It may be advantageously combined with the slate yeast storage vessel already described; in which case all the yeast required for pitching is transferred from the bags to the storage vessel, as soon as it is of the proper consistency, and the yeast not required for use in the brewery is allowed to drain until all the beer it contained is returned to the fermenting tun. When used in this combination the depth of the yeast storage vessel may be reduced to about eight inches and no copper pipe attemperator is required.

I have already alluded to the necessity of aerating the wort, both when boiling hot and after it is cooled; air must be also supplied to the fermenting beer, especially during the later stages of the process.

When beer is cleansed this aeration is effected naturally, and without the necessity for the use of any special apparatus; but on the skimming system special precautions must be taken, or the fermentation in its later stages will become sluggish, and the yeast will not separate freely from the beer, hence the necessity for rousing.

On the stone square system this aeration is effected very perfectly by means of a hand pump. A certain quantity of beer is pumped up at intervals to the yeast trough, where it is whipped up with the air and yeast, and the whole returned to the beer in the square. This system might easily be modified so as to render it applicable to ordinary fermenting tuns.

Besides the supply of air to the beer, the mere mechanical action of rousing is of great importance, for it has been proved that motion is necessary to maintain the healthy action of the yeast cells, and further that

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the motion caused by the escape of the carbonic acid from the beer, is not in itself sufficient, but must be supplemented by mechanical means, if the best results are to be secured.

Rousers are made of many different forms, some of which are best adapted to be worked by hand, while others require steam or other power.

Of the hand rousers, the best consists of a small cask of about three gallons capacity, open at both ends. A number of one-inch holes are bored in the staves, and the cask is suspended by a rope fastened to the centre of one of the staves. This rope passes over a pulley fastened above the centre of the tun, and by it the cask is easily raised or lowered. A stout piece of lead about one inch thick, four inches broad, and the length of the staves, is fitted carefully to the cask, and fastened opposite the point of suspension. By lowering this cask into the beer, and then raising it quickly to a short distance above the surface, a very effectual rousing, and a sufficient aeration is secured.

There are numerous forms of power rousing and aerating apparatus. Some of these use a screw propeller as the rouser, and pump air in by means of a species of bellows. Others produce a slow wave-like motion in the beer, by means of paddles with a reciprocating motion. Both these plans seem to answer well. Then again air has been forced through the beer by means of pumps, rousing and aerated it at the same time, but I think this arrangement produces an excessive aeration of the beer, in proportion to the motion produced in it, and is therefore objectionable.

A centrifugal pump is perhaps, the best power rousing and aerating apparatus of all. It must deliver a large

stream to a regulated height above the surface of the beer, this height being capable of being varied from a few inches, to two or three feet at the will of the operator. The suction and discharge pipes must be of large diameter, three inches being about sufficient for a hundred barrel tun.

Fermenting tuns which are worked on the skimming system must always be furnished with such an arrangement of cocks as will enable the beer to be racked free from any yeast which may have settled to the bottom of the tun. For this purpose either two cocks should be employed, or a screw cock constructed like those used for the Burton unions, and which, will be described with them. Probably the two cocks will generally be found most convenient, one of which should be placed so as to leave at least two inches of beer in the tun, all the clear beer being drawn off through this cock. The other cock is fastened to the bottom of the tun at its lowest point, so that it will drain it, and a thimble is screwed into a plate fastened immediately above this cock. This thimble when screwed up, so as to project as far as possible into the tun, stands up one and half inches, and can be screwed down by means of a T spanner until its top is level with the bottom of the tun. In this way all the beer left in the tun by the first cock, can be run into a tub with as little yeast as possible, and there allowed to settle, or it may be filtered. This second cock is also used for washing out. The first cock may have a racking pipe and cocks fitted to it, so that the beer may be racked direct from the fermenting tun into the trade casks.

Instead of the two cocks just described or the screw cock, a single cock with a long tail pipe passing through

a stuffing box fixed to the lowest part of the tun, may be employed. The entreme end of this pipe is furnished with a ferrule, which when the pipe is withdrawn as far as possible, fits into a recess formed in the upper part of stuffing box, so that the mouth of the pipe, is in that position level with the bottom of the tun. This pipe can be either moved up and down by hand, or a screw or lever may be employed to move it with greater accuracy. When the beer is to be drawn off clear of yeast, the cock and pipe are pushed upwards, until the top of the latter is sufficiently raised above the bottom of the tun, to prevent any chance of yeast or other sediment being disturbed. When the yeasty head approaches the orifice of the pipe too closely, the cock and pipe are gradually withdrawn, and the more or less muddy beer is run into a tub to settle. Finally, the ferrule at the upper end of the pipe is withdrawn into the recess, the yeasty bottoms drawn off, and the tun washed out. The ferrule prevents all risk of the pipe being withdrawn too far. This convenient arrangement has been introduced by Messrs. G. J. Worssam & Son.

I have already described the simple form of fermenting tun which is required when the cleansing system of fermentation is adopted. This system in its simplest form consists in running the beer direct into the trade casks while the fermentation is still in full vigour, and completing the process in these casks placed on troughs called stillions, which receive the yeast as it works out of the bungholes. As these stillions are simple wooden troughs supported on legs, and as the only other apparatus required is a good hose, there is nothing further for me to describe under this head. Cleansing direct into the trade casks answers well for the commoner beers, but

high-class malt liquors require racking free from bottom yeast, into the trade casks, and I shall now proceed to describe the more important forms of apparatus, in which the cleansing process is usually carried out in modern breweries.

One of the simplest and most efficient forms of cleansing vessel are the "loose hogsheads," which were in almost universal use in Burton previous to the introduction of unions.

These "loose hogsheads" are usually puncheons, holding from three to four barrels each, they are placed on gantrees and provided with bung and tap holes. Into the bunghole a short conical tinned pipe is inserted, which can be stopped at the top with a wooden plug, and from which a branch of about two inches diameter proceeds, so as to project some inches beyond the head of the puncheon. Troughs or tubs are placed in front of the puncheons, and the yeast works into them, through the above branch pipes. The puncheons are filled up through the short conical pipes. These pipes are removed each time the puncheons are emptied, and the latter having no fixed connections, are rolled out and washed in the brewery yard, thus avoiding the use of large quantities of boiling water in the fermenting rooms, a matter of considerable importance in the warmer months. I believe the use of loose hogsheads to be as efficient as any system in vogue, and perhaps preferable for the production of sound beer, even to the fixed unions.

It is also not difficult to arrange mechanical means for filling them up, by which the labour is reduced as far as possible, and does not much exceed that required on the union system. I should always advise the loose hogsheads to be employed in small breweries, as their first

cost is not great, and the plant can be increased to any extent that space will permit. They are, however, not economical in this latter particular. When the beer is sufficiently fine, a tap is inserted at the tap-hole, and the contents of the puncheon either racked direct into the trade casks, or run first into a settling square.

Mr. J. W. Clinch, of Douglas, Isle of Man, has given me the following description of a modification of the above "loose hogshead" system introduced, I understand, many years ago by his uncle, and which in his hands works well. The same sized puncheons are used as in the system just described. These puncheons are each of them furnished with a screwed brass bush, fitted into the bungholes. Shallow tubs of 52 gallons capacity also have similar bushes fitted into the bottom of each, and there is one such tub placed above each puncheon, and connected with it by means of a pipe nine inches long and three inches in diameter. This pipe projects into the tub six inches and has several holes of three-eighths of an inch in diameter bored in it, just on a level with the bottom of the tub. When the beer is ready for cleansing, it is run into the tubs and puncheons, until it stands about two inches deep in the former, and I may remark that the practice is to cleanse the beer much earlier than usual, viz.: in from sixteen to twenty hours after it is all in the collecting vessel.

The fermentation and cleansing proceed automatically, and without requiring any attention, for as fast as the head works out into the tubs it is replaced by the beer in the latter, draining into the puncheons, through the small holes in the pipes.

When the fermentation is completed, which generally occurs in from four to five days, the small quantity of

beer still remaining in the tubs is drained out and used afterwards for topping up, and the tubs with the yeast adhering to their bottoms removed. This yeast is then ready to be used for pitching.

The beer is run into a settling back with a floating cover, to exclude the air as far as possible, and allowed to remain until ready for racking.

It is necessary to keep the fermenting rooms at a temperature not exceeding 58° F., or this system does not work well—no doubt owing to the yeast not separating with sufficient rapidity from the beer, and being consequently carried back with it, through the small holes into the puncheons.

Burton unions may be considered as the perfect development of the loose hogshead system of cleansing. They consist of a double row of casks, which usually contain four barrels each, but they have been made as small as a barrel and a half; this, however, was quite an exceptional experiment for the purpose of more fully carrying out attemperation by subdivision.

These casks are hung on trunnions working on bearings supported by solid wooden frames. The external trunnion of each cask has a square head projecting beyond the bearing, to which a moveable winch handle can be fitted, so that when the casks are to be washed, the boiling water having been run into them, they are bunged up and rapidly revolved, by which means every portion of the cask is thoroughly cleansed.

In addition to the union casks, and supported above them on the same frame, are the feeding and yeast troughs. They are usually connected with the casks by fittings, which I will describe.

The casks, in the earlier arrangement of unions, were

filled from the yeast trough by means of descending pipes, with other tubes sliding on them, entering the casks at the bung-holes, which could be made temporarily tight by means of a lap of flax; after the cask was filled, the orifice of the pipe in the yeast trough was closed by a long wooden plug. These connections between the yeast trough and the casks are now usually dispensed with, the casks being filled through the same pipes which are used for feeding. From the feeding trough, a pipe running the whole length of the series of casks is connected by branches with each above its centre by means of a screw union and tap, the tap being permanently fixed in the cask. Inch pipes, or even less, were formerly used when they were only employed for feeding, but two-inch pipes are now substituted, so that the casks can be filled through them with sufficient rapidity.

To carry the yeast as it works off from the cask to the trough, a peculiarly shaped pipe, termed the swan neck, is fitted by means of a hollow conical brass plug into a ground brass socket, fixed at the highest part of the cask. The swan neck is almost invariably constructed of tinned copper pipe, and ascends from the plug to a little above the side of the trough, over which it is curved, so as to deliver the yeast freely into the trough.

There are several ways of transferring the beer, which separates from the yeast, to the feeding trough. For instance three or four small plug-holes may connect the one trough with the other. These holes are each at a slightly different level from the other, and all within a short distance of the bottom of the yeast trough. By carefully noting at which of these the beer will run

tolerably clear of yeast, it is generally possible to secure a sufficiently bright feed. As, however, the least carelessness on the part of the man superintending the fermentation involves the introduction of a yeasty feed, which is sure to cause the formation of bottom yeast and its attendant evils, some prefer to draw off the whole of the beer which separates from the yeast by means of a screw tap into separate tubs, and not to transfer this beer to the feeding-trough until it is sufficiently bright. Another excellent plan is to pump all the yeast into Southby's patent filtering apparatus, so placed that the bright beer runs direct from the filter bags into the feed trough.

The two methods adopted for feeding are the intermittent and the continuous. In the former case the main tap from the feeding-trough to the casks is opened at fixed intervals, and allowed to remain so until the whole of the yeast is expelled and the casks are quite filled with beer. In the latter, the feeding beer passes first from the main feed trough into a small cistern, in which it is maintained at a constant level by means of a ball-cock, this level being about three inches above that of the tops of the union casks into which the beer flows as required.

When the fermentation is finished, the beer is drawn off by means of what are termed "screw taps," one of which is fixed at the lower part of each of the casks. These taps enter the casks through a screw collar, and when they are screwed home, jam a leather washer between the flange on the tap and that on the collar. In this position the screwed pipe of the tap projects about six inches upwards into the cask, and when the beer has been drawn down to this level, the tap is gradually screwed

lower as long as the beer runs bright; this description of tap is that alluded to above for drawing the beer from the yeast-trough. The beer flows from these taps through troughs placed immediately below them into large tanks, capable of holding one or more brewings, from whence it is racked into the trade casks; by this means uniformity of attenuation is better attained than by racking each union cask separately.

The Burton union system, especially for winter work, is perhaps the best that can be devised; and by it a very perfect command over the temperature and rapidity of the fermentation is obtained, so long as the union rooms can be kept at, or but little over, 50°. During the summer, however, artificial attemperation must be resorted to, and there are now several forms of attemperator adapted for use, both in the union casks and in the yeast and feed troughs, which enable the brewer to continue the ordinary work of the union room uninterruptedly throughout the summer months.

On the union system the arrangement of the vessels enables the yeast to clear itself thoroughly from the beer, which is also well protected from the air during the dangerous period which intervenes between the vigorous stage of the fermentation and the beer being sufficiently bright for racking. The fact of the casks being washed without removal also very much diminishes the labour and saves space. This, however, has one drawback, for it involves the heating of the union room by the large quantity of boiling water which has to be employed.

The cleansing vessels known as pontos were formerly much more in vogue than they are at present. As commonly constructed, sufficient precautions were seldom taken to enable either the inside or outside of these

vessels to be kept clean and free from yeasty and other foul deposits. When, however, pontos are erected in such a manner that with ordinary care that scrupulous cleanliness can be secured which is so essential in every department of the brewery, they form efficient cleansing vessels for stout, porter, and the commoner class of ales.

Pontos are usually small squares or rounds, headed in at the top, and with a man-hole through which the yeast overflows into the yeast trough. One yeast trough is usually placed between two sets of pontos, and is provided with a plug-hole through which the beer is allowed to flow, as it separates from the yeast, into the settling trough which is placed below. From this trough it is pumped up into the feeding tun, which is placed above the level of the pontos, and is sometimes provided with a parachute skimmer to remove any yeast that may gather on its surface. The flow of the beer from the feeding tun is regulated by a ball-cock placed in a small cistern, which just commands the pontos so as to keep them always full.

Various modifications of the ordinary pontos have been introduced at different times, but none of these arrangements appear to me to possess any special advantages, and my opinion is that brewers who decide on working on the cleansing system should use "loose hogsheads" if their breweries are small, and Burton unions in large breweries.

In the Scotch ale breweries the beer is usually cleansed towards the close of the fermentation into a skimming square. These skimming squares are made much shallower than the fermenting squares, so as to facilitate the separation of the yeast from the beer, which is racked direct from them into the trade casks, and the same

precautions are adopted as regards the position of the cocks, as have been already described in the case of squares worked on the ordinary skimming system.

In most of the great Dublin and other Irish porter breweries another variety of skimming square is adopted, which is in the form of a trough running the whole length of the room, and about six feet wide by three or four deep, a second smaller and shallower trough standing alongside. The side of the larger trough adjacent to the smaller one is a few inches lower than the other sides, and over it the yeast is pushed by means of a board into the smaller trough. In some Irish breweries the yeast trough is placed at the end instead of adjacent to the side of the skimming vessel.

For black beers the above plan of cleansing and skimming appears to answer well. I may add that these long vessels or troughs as I have called them are usually both made of cast iron.

In speaking of the Burton unions I have already alluded to racking squares. These vessels may be constructed of wood like the fermenting squares, in which case the same qualities of material and precautions in construction should be adopted as I have already set forth. Slate is, however, the material best adapted for the construction of racking and settling squares, and I have already described the construction of slate squares.

In Burton breweries the racking squares are sometimes made of sufficient size to hold two brewings so that the whole of two brewings may be at once blended together; but I think the better plan is to make them large enough to just hold one brewing only. They must not exceed four feet in depth and may be made somewhat shallower with advantage.

There must be a sufficient number of taps at convenient intervals to enable the trade casks to be filled rapidly. These taps may be advantageously inserted within an inch of the bottom of the square, which must be supported at such a height from the ground that the nozzles of the taps are about forty inches from the floor: this will enable the largest casks to be filled without inconvenience. At the time of racking, canvas hose are tied to the nozzles of the taps of sufficient length to reach to near the bottom of the casks through the bung-holes.

Racking squares are used both on the union and also very frequently on the skimming systems. They insure the whole of each brewing being uniform in quality, but they are liable to flatten the beer. This is of no consequence in the case of stock beers, but is a serious matter when the beers are required for immediate consumption. In order to reduce this flattening to a minimum the settling square must not be too large, and the beer in it must be from three to four feet deep when the gype is all run down. The beer should be let down gently on to the bottom of the square, and must on no account be allowed to dash or splash into it. It is also a good plan to have close fitting covers which will exclude the air and keep in the carbonic acid as much as possible. These covers, however, should be moveable, so that the square may be opened for cleaning. A floating cover is perhaps the most efficient form for this purpose.

I prefer to rack the beer on the skimming system direct from the fermenting tuns into the trade casks, but this is not always possible owing to the height of the tuns above the racking room, being so great as to cause frothing. In such cases a very useful vessel consists of

an ordinary slate racking square with a partition separating it into a smaller and larger portion. The smaller division of the square has the racking cocks attached to it, and is provided with close fitting covers removeable for cleaning. It communicates with the larger division by means of a bent pipe communicating with the bottom of both divisions. This bent pipe is closed by means of a screw plug when only the small division of the square is being used. By removing this plug the whole vessel becomes practically one large racking and settling square.

The beer is admitted into the smaller division of this form of racking square through a valve attached to a float, and a hose conducts the beer from the fermenting tun. The end of this hose is connected with one end of a pipe by means of a union, and the above valve and float are fixed to the other end of this pipe which projects into the square. When the beer is turned on from the fermenting tun it flows through the hose, the pipe and the valve into the square, and as soon as the latter is full the float closes the valve until some of the beer is racked off.

In this form of racking square, the smaller division is alone used for beers intended for immediate consumption, but when stock beers are to be racked, the screw plug is removed, and the whole vessel can then be used as a settling square.

CHAPTER XII.

BEER STORAGE, CASKS, VATS AND CELLARS.

THE methods of storing beer in different parts of the United Kingdom vary considerably. In Burton the beer is run into the trade casks, and these are often stacked in the open during the winter months, and only placed under cover as the season advances. In other localities the trade casks full of stock beer are stored in underground cellars, where a very uniform temperature is maintained. Of these two plans, the former answers well if the beer is sound and good enough to stand it, but if there is any doubt on this point the latter plan must of course be adopted.

Then again, black beers and old ales are frequently stored in vats, and vatting greatly improves the quality of these varieties of malt liquor. I must, therefore, in this chapter consider the construction of casks, vats and cellars, with the appliances for raising and lowering casks of beer in the latter.

Casks are generally made of foreign oak, although in some country districts where oak is abundant, the coopers and brewers occasionly use English oak. This latter has to be sawn into staves, as the grain is not straight enough

for splitting. Foreign staves are all split, and then roughly planed.

The qualities of foreign oak staves used for casks are as follows :—

Stettin, which is the best quality of all, but is now very scarce. Memmel, this is what is now generally used for the best quality. Dantzic, which is the next best quality. Odessa, Blumeza, and Riga are some of the other qualities.

Casks are generally classed as either stout, intermediate or slight. The following table will give some idea of the thickness of the wood in each of these qualities, and also the substance of the iron with which they are hooped.

SUBSTANCE OF TIMBER.				WIDTH OF HOOPS.		
		Staves	Heads	End	Bulge	Quarter
		in.	in.	in.	in.	in.
Hogsheads	Stout	1½	1½	2½	2	1¾
	Intermediate	1¼	1¼	2¼	1¾	1½
	Slight	1	1⅛	2¼	1¾	1½
Barrels	Stout	1½	1½	2½	2	1½
	Intermediate	1⅛	1¼	2¼	1¾	1½
	Slight	1	1⅛	2¼	1¾	1½
Kilderkins	Stout	1¼	1½	2¼	2	—
	Intermediate	1⅛	1¼	2¼	2	—
	Slight	1	1⅛	2	1½	1⅜
Firkins	Stout	1¼	1¼	2	1¾	—
	Intermediate	1⅛	1⅛	2	1½	—
	Slight	1	1⅛	1¾	1½	—

Vats should be made of English oak. In the previous chapter I have given particulars as to their construction.

Vats are liable to the attacks of the fungus which

produces dry rot, and should be periodically examined so as to detect the first symptoms of its appearance, so that it may be at once eradicated.

In the construction of cellars the objects to be aimed at may be briefly stated to be uniformity of temperature, and convenience of arrangement, for handling the beer stored in them.

Beer must be very badly brewed, if it will not keep for any reasonable length of time sound and in good condition at a temperature of 55°. If, therefore, such cellarage can be obtained, even at the cost of what may be termed a considerable outlay, as will enable the brewer to store his beer throughout the summer at a temperature of between 50° and 55°, an insurance against loss from beer going sour during the hotter months is effected.

It cannot, however, be expected that cellars of this perfect construction are always to be secured or constructed. In many places the natural water level is so near the surface that it is impossible to excavate to a sufficient depth to accomplish this end. Where, however, cellars can be made of a sufficient depth without liability to flooding, a few precautions are necessary to secure the greatest advantage.

All cellars should be excavated below other buildings, which serve to shield them from the direct effect of external temperature. For the same reason it is well to have the cellars vaulted with good brickwork, and the openings—which should be as few as possible—should pass directly downwards through the vaulting, side or lateral openings being avoided as far as possible.

As long as the cellar entrances are few, and arranged in the manner indicated, the most advantageous

construction of cellarage will depend upon the nature of the situation and other matters of convenience, which will have to be studied in detail to suit the requirements of various localities.

In positions where it is possible to excavate cellars underground, their construction in many localities adds but little to the original cost of the brewery; it is therefore always advisable when about to erect a brewery to make the cellarage as large and ample in every way as circumstances will permit. I have seen instances where advantage was taken of the nature of the chalk formation to excavate a double tier of cellars, one below the other, which arrangement ensured storage of the most commodious and perfect description.

The localities most favourable for the construction of cellars are manifestly those in which the underlying strata are at the same time sufficiently soft to allow of their being easily excavated, and sufficiently compact to form secure walls for the cellars without the assistance of any large amount of brickwork. Many varieties of chalk and sandstone, and some limestones, fulfil these conditions, and in some cases the cost of constructing cellars is still further reduced, by the stone excavated being of sufficiently good quality to be used in building the brewery itself. Under such favourable conditions extensive cellarage should always be constructed before the building of the brewery is proceeded with. It is comparatively cheap and easy to excavate cellars before there are any buildings on the ground, but when once the brewery is erected the cost of any further extension of the underground cellars is sure to be doubled, if not trebled, compared to what it would have been if the cellars had been made first.

Every precaution should be adopted to keep cellars as dry as possible. Dampness in cellars gives rise to a variety of most objectionable growths, which injure the woodwork of the casks and vats; and it also rusts the hoops. Then, again, the conductivity of damp air is so much greater than that of dry air, that when the air of a cellar is damp, a considerable portion of the natural coolness of the situation is lost.

Even underground cellars, unless excavated to a great depth, are liable to considerable variations of temperature, and these variations are frequently aggravated by inattention to the rules I have already laid down. In this connection the lighting of cellars is a matter of considerable importance. For instance, it is manifestly useless to expect to keep down the temperature so long as a number of gas lights are left burning without any notice being taken of the extent to which the combustion must naturally warm the air.

In many cases a well arranged system of reflectors may be used in order to bring daylight into the cellars. Then again, the electric light is perfect for illuminating cellars, but its great cost at present almost precludes its adoption, except in those rare cases where there is an excess of water power to be had for little or nothing.

When gas or other lamps have to be resorted to, they should only be kept burning when absolutely required. In many cases portable lamps may be substituted with advantage for fixed lights.

As regards the exact temperature which ought to be maintained in cellars; I think that for stock beers it cannot well be too low, but it is not safe to adopt this rule in the case of beers which are to be sent out for

immediate consumption, a week or two after they are brewed. In the case of these latter beers, the temperature of the cellar should not be allowed to fall much below 55° F, and it is generally advisable to have some means of artificially heating such cellars. The gas jets used for illumination may be utilised for this purpose where gas is cheap, but cast iron pipes heated by either steam or hot water, give more perfect control over the temperature, and at less expense. The ordinary hot water apparatus with a system of cast iron pipes is sometimes used, but I think steam is in most breweries a cheaper and more convenient heating medium. Either steam or hot water should be used for heating, not only the cellars, but also the fermenting rooms in very cold weather. Cressets with coke fires burning in them, were used formerly; but they are both dangerous and dirty, and ought to be everywhere abolished.

What is the best floor for a cellar is a question frequently asked, and certainly the frightful stench arising from many cellar floors, proves that there is often room for improvement in this detail of brewery construction. There are two principal requirements for a cellar floor, viz.: imperviousness, and durability. Now there are plenty of flooring materials which are impervious, and also a good many which are durable, and will stand casks being constantly rolled over them without injury, but there are few materials which combine both these valuable properties.

Whatever floor is going to be laid, the first thing is to give it a substratum of not less than six inches of good concrete, and under some circumstances nine inches of this material is none too much, of course, this thick bed of concrete is not necessary when the natural floor is

solid rock. The floor which it is most advisable to lay on this concrete depends upon various circumstances.

Thus when economy is an object of first importance, a cement floor may be laid, and if the work is well done it will last for some years, especially if boards are temporarily laid down, when any large number of casks have to be moved. When a more durable but still an economical floor is required, asphalt may be used, and if it is only of a sufficiently good quality, properly laid, and of a sufficient thickness, an asphalt floor is very durable, and has the valuable property of being absolutely impervious. In localities where good hard flags can be obtained at a moderate cost, they make a first-class cellar floor, when laid on a good bed of concrete, provided the joints are rendered impervious, by being carefully and thoroughly closed with cement. Where flags are expensive, hard black bricks may be used, well jointed and laid in cement on the concrete bed, but unless they are very hard and well laid they do not make a good floor; and finally, where the wear and tear is enormous, owing to the constant passage of heavy casks, granite blocks laid on a thick bed of concrete, and the joints filled in with asphalt, constitute a perfect but very expensive floor.

Besides the above there are some patented compositions such as the Granolithic, which have been tried by some brewers, but with what success it is perhaps too early yet to decide. These compositions are usually varieties of cement, and can only be superior to that material, to the extent of their increased hardness and durability.

As a hint to small brewers whose cellar floors are bad, and who cannot go to the expense of a good new floor,

I would say, keep your floors dry if possible, for the wetter they are the more they will stink.

The forms of apparatus used for raising and lowering casks in connection with brewery cellars, may be classed under the two heads of hydraulic lifts, and those in which some other power is used.

The hydraulic lift is best adapted for breweries of moderate size, and where a supply of water can be procured at a sufficiently high and constant pressure, they are very convenient. Forty pounds per square inch is about the lowest pressure of water by which these lifts can be worked with advantage. They can of course be worked by means of a hydraulic pump, which may either be driven from the main shafting, or as a donkey pump. When driven by a pump, the pressure can be increased to almost any extent, and the diameter of the ram proportionately diminished.

For large breweries, the cask elevator is by far the best form of apparatus, as it will raise an enormous number of casks in a very short time, and with very little labour. It consists of two diagonal frames, with revolving drums at both the top and the bottom. Endless chains, one on each side, revolve on these drums, and carry horns, each pair of which engages one cask, raises it to the required height, and delivers it on to the loading stage.

I cannot advise the use of any of the other forms of cask lift. In all cases in which it is decided not to use either a cask elevator or a hydraulic lift, the brewer had better be content to roll his casks up an ordinary incline or pulley, just in the same way that he loads and unloads his drays.

CHAPTER XIII.

STEAM BOILERS, STEAM ENGINES, CASK-STEAMING AND WASHING APPARATUS.

THE steam boilers belonging to a brewery, must have ample steam and water space, so that they may be able to meet the excessively irregular steam requirements. All those ingenious forms of boiler, which hold little water, such as the Roots and other tubular boilers, are therefore utterly unsuitable, and vertical boilers should never be used, except in cases where want of space compels their adoption. Those boilers which are made on the plan of the locomotive boiler, with a large fire-box and numerous small tubes, proceeding from it, are spoken highly of by some of my friends, but I myself greatly prefer some one of the recent modifications of the old Cornish boiler, and the very best of these is certainly the Galloway. By a Galloway boiler I do not mean any of those forms with one or more flues, and a certain number of Galloway tubes in them, although some of these answer well, but I mean the new Galloway boiler, with the kidney-shaped flue, fitted with vertical tubes, and which certainly appears to me to be the perfection of a boiler for a

brewery. This form of boiler is safe, it has a large water and steam space, can be easily and thoroughly cleaned in all parts, and is very economical in working.

Steam engines for breweries should be well and solidly constructed, but they should be as simple as possible. And this is especially the case in small breweries, where they have frequently to be left in the charge of men of no great engineering skill or knowledge. There are so many makers of excellent steam engines, that to particularise would be both useless and invidious; but let the brewer beware of cheap engines, by unknown makers, as they will soon double their prime cost in repairs and waste of steam. The wisest plan is to purchase of a well-known maker, and to pay him a fair price for an engine that he will guarantee. I may remark further that every brewery engine of any considerable size should be fitted with automatic expansion gear.

There are a great many arrangements, forms of apparatus, and processes for cleaning casks; and cask washing and cleansing is a matter of vast importance to the brewer. But I am not at all sure that the most elaborate machines possess all the advantages claimed for them. The fact is that the washing and thorough cleaning of casks in a brewery is a matter that requires so much personal attention from the men employed, that elaborate machinery is to a great extent thrown away. In this, as in so many other instances, if a man has to watch a machine very carefully, he may just as well do the work by hand. I therefore doubt the utility of the mechanical cask washers, except in the case of large breweries.

When the dirty casks returned to the brewery are

examined, they can be quickly divided into those which cannot be cleaned without one of the heads being taken out, and those which can be washed perfectly clean as they stand.

If the head is taken out of a cask, no machinery is required to clean it, and the greater number of those which do not require their heads removed, can be quickly cleansed by washing with hot water, and subsequent steaming. The mechanical cask washer, only effects a saving of labour on a small percentage of casks, which are rather too dirty to wash by hand without the removal of the heads, and are yet not foul enough to render that operation absolutely essential. In large breweries however these machines are no doubt useful and save some labour.

Every brewery should be provided with a sufficient number of cask steaming nozzles, and also with a large tank of water, kept up to the full boiling temperature by means of free steam. A blower and set of air nozzles for drying the casks after they have been washed and steamed, is also a most valuable apparatus, and one which is far too often omitted.

It is by no means necessary to heat the air which is blown into the casks to dry them, all that is essential is that the casks should be thoroughly heated by washing with boiling water, and steaming, and should then at once have a strong current of air forced through them, while the wood is at a high temperature.

There is a simple apparatus for washing casks, which is often useful, and is now much resorted to in breweries. I allude to that arrangement of pipes and cocks by which water and steam are admitted together into the casks, and the water thus boiled in them. The mechanical

action obtained does, no doubt, assist in washing the casks, and there can be no objection to the use of this apparatus, provided it is not expected to do much more than supply boiling water in a convenient way. The casks, however, after they are thoroughly cleansed by means of this apparatus, supplemented as far as necessary by manual labour, must be steamed and dried, so that there is not after all much saving effected, as compared with washing the casks with boiling water from a tank.

Besides the above appliances every large brewery should have an iron pan, in which a solution of common washing soda can be boiled, for treating sour casks ; and also a tank into which the soda liquor can be emptied from the casks, for this liquor can be used over again for a good many times before it is necessary to renew it. The washing soda and water are first boiled in the pan, and the casks filled with the boiling hot liquor. After standing with the liquor in them for three or four hours, they are emptied into the tank, washed several times with clean water, steamed and dried. The liquor is pumped up again to the pan, by means of an iron rotary pump, boiled, and used for another lot of casks. When it becomes too foul for use it is run to waste.

Permanganate of potash is now largely used for curing stinking casks, and is very effectual, no special apparatus is, however, required for applying it.

For curing acid casks, in breweries which have no soda pan, quicklime is a cheap and effective substitute. It should be slaked with boiling water into a powder. One quart of this powder is generally enough for a barrel; the powder should be mixed with water, and introduced into the barrel, which is then filled with water, allowed

to stand for at least twelve hours, and afterwards washed, steamed and dried.

It is a very good and safe plan to wash out all the casks with a little bisulphite of lime, after any of the above treatments with alkaline substances. The bisulphite should be applied shortly before steaming, and well rinsed round every part of the cask. All casks may be rinsed with bisulphite after they are taken off the steaming-nozzles, and before being placed on the drying-nozzles.

CHAPTER XIV. SECTION II.

MATERIALS GENERALLY—WATER.

THERE are three materials which are essential to the composition of what is now known as beer, and a proportion of all three of these materials must be used in brewing anything that can now be properly called beer.

These materials are Water, Malt, and Hops; and if a pure beer is to be brewed each of them must be free from impurities, and must also contain those substances which are essential to its constitution as a brewing material.

Beer was not always brewed from the above three materials. No doubt grain of some sort and generally more or less malted supplied the saccharine matter, and water must always have constituted the great bulk of the liquid, but the use of hops is a comparatively recent innovation and one that was by no means tamely submitted to at the time of their first introduction either by the public at large or by the growers of other bitters.

Hops, however, after a time established their superiority to all other bitters as a brewing material, and although I think that it is not only permissable, but even advisable, in seasons when hops are scarce and of inferior quality, to assist their action by the addition of a small proportion of other equally wholesome bitters and astringents,

still hops must undoubtedly be reckoned together with malt and water as constituting the three essential materials for the manufacture of beer.

As water constitutes from about seventy-five to ninety per cent. of all beers it may be looked upon as the most important of the above three materials. I will therefore give it precedence over the two others, which I will afterwards consider in the order in which I have named them.

Water is composed of one part by weight of hydrogen, combined with eight parts of oxygen. This combination constitutes chemically pure water, which may be obtained by various more or less expensive and troublesome processes, but even if we could procure an abundant supply of this chemically pure water it would not constitute a good brewing material. A good brewing water must no doubt be as free as possible from those soluble matters which are derived from the decomposition of organic substances, but it must at the same time hold in solution certain saline ingredients, and it is only with a water which contains them that good beer can be brewed.

These saline ingredients may either be naturally derived from the strata through which the water has percolated, or they may be added artificially to the water, in either case they are essential, and when I speak of water as one of the essential brewing materials, I mean water containing these saline ingredients; whether they are naturally present or are artificially added is a matter of small importance.

Different classes of beer require different saline ingredients, and I think I cannot commence the consideration of what these should be, better than by giving the analysis of some of the most famous brewing waters of this country.

The following analyses I have taken from my laboratory book. They are all made by myself and of brewing waters actually in use, several of them in our largest and most famous breweries. I have selected them from numerous others as typical of each class of brewing water, but it must not be supposed that the waters of any one class or locality are always identical in composition. The waters of each class have, however, a certain general resemblance which gives them their characteristic properties, and distinguishes each of them from all the others, in a more or less marked manner.

In each of the following analyses I give firstly the analytical results, and secondly the proportions of the various salts which those results probably indicate, as present in each water. I only give here the inorganic constituents, as I shall treat of the organic matter in brewing waters later on; these organic matters being injurious impurities and not essential ingredients.

BURTON BREWING WATERS.

1st. From the valley gravels overlying the red marles of the Trias formation. It is from this source that the great bulk of the Burton brewing water is obtained.

	Grs. per Gall.
Carbonates of lime and magnesia precipitated on boiling	11·4
Lime not precipitated on boiling	17·7
Magnesia not precipitated on boiling ..	4·3
Sulphuric acid	33·9
Chlorine	3·0

or combined—

Carbonates of lime and magnesia	11·4
Sulphate of lime	43·0
Sulphate of magnesia	12·9
Alkaline chlorides	5·0

The above analysis was made many years ago, but analyses which I have made of the waters from these Burton valley gravels during the last few years give similar results. When these waters are pure their composition is the same now as it was thirty years ago, and their most marked characteristic is that the amount of sulphuric acid is just sufficient to combine with all the lime and magnesia present in the water, and not precipitated from it on boiling in the form of carbonates. The proportion which these sulphates bear to one another varies slightly, but is roughly as three of the lime sulphate to one of the magnesia sulphate. The dilution of these waters varies much more, than the proportion of the salts to one another in any one water. Thus in good Burton brewing waters the carbonates of lime and magnesia vary from ten to nearly twenty grains per gallon. The sulphuric acid from fifteen to over forty grains, and the chlorine from two to three and a-half grains. Within these limits of dilution beers can be brewed with the true Burton characteristics, but the best results are obtained with waters containing from eighteen to twenty-eight grains per gallon of sulphuric acid. My remarks on these waters only apply in their full force to such as are free from organic impurities, and from their oxodized products; which latter, in the form of nitrates, now contaminate, to a greater or lesser extent, the majority of the Burton wells situated within the town. A brewer using a pure Burton water can scarcely fail to produce a brilliant delicate and delicious ale, if his malt and hops are of moderately good quality; but it is far otherwise with the contaminated springs which so many Burton brewers have now to depend upon.

The other source of Burton brewing water is from

borings sunk to various depths into the marls underlying the valley gravels. These borings are very uncertain, for sometimes one boring will yield a large supply of water, and another sunk within a few yards of it to an equal or greater depth, will yield no water at all.

The following is an analysis of a pure and good water from one of these borings :—

	Grs. per Gall.
Carbonates of lime and magnesia precipitated on boiling	15·4
Lime not precipitated on boiling	25·5
Magnesia not precipitated on boiling ..	10·2
Sulphuric acid	56·8
Chlorine	2·5

or combined—

Carbonates of lime and magnesia	15·4
Sulphate of lime	61·9
Sulphate of magnesia	30·6
Alkaline chlorides	4·2

This water is evidently of the same general character, as those from the valley gravels, but it is more concentrated, and the proportion of the sulphates is two of lime sulphate to one of magnesia sulphate, instead of three of the former to one of the latter.

I will now pass from the ale brewing waters of Burton to the waters of those localities which are famous for their black beers, and as Dublin has of late years taken the lead in stout brewing, I will give an analysis which I have lately made of the Grand Canal water, from which by far the largest proportion of the finest Dublin stout is brewed.

	Grs. per Gall.
Carbonates of lime and magnesia precipitated on boiling	11·0
Lime not precipitated by boiling	0·9
Magnesia not precipitated by boiling ..	0·9
Sulphuric acid	0·5
Chlorine	1·2

or combined—

	Grs. per Gall.
Carbonates of lime and magnesia precipitated on boiling	11·0
Sulphate of lime	0·8
Chloride of calcium	1·1
Chloride of magnesium	0·7
Carbonate of magnesia not precipitated on boiling	1·2

The contrast between the composition of this Grand Canal water and the Burton brewing water cannot fail to strike every reader. The great difference between the two waters consists in the almost total absence of those sulphates from the former, the presence of which in the Burton waters constitutes their marked characteristic. The other points worthy of notice in the Dublin water are the small amount of chlorides which it contains, and the very distinct alkaline reaction of the boiled water. This alkaline reaction is caused by the presence of carbonate of magnesia, and also of those alkaline silicates which, although I have not hitherto alluded to them, are present in small quantities in the Burton, Dublin, and most other good brewing waters.

This Grand Canal water derives its origin, I believe, from limestone springs, and it closely resembles the magnificent and unfailing supply of pure brewing water which is available in the chalk districts of the South of England and other localities.

The following is a typical example of a pure chalk water:—

	Grs. per Gall.
Carbonates of lime and magnesia precipitated on boiling	14·2
Lime not precipitated by boiling	1·1
Magnesia not precipitated by boiling ..	0·1
Sulphuric acid	0·6
Chlorine	0·9
Nitric acid	0·2

or combined—

	Grs. per Gall.
Carbonates of lime and magnesia	14·2
Sulphate of lime	1·0
Chloride of calcium	1·4
Nitrate of magnesia	0·3

I come now to the consideration of the London brewing waters. These were formerly derived from the rivers Thames and Lee, and from shallow wells ; but all these sources of supply have now become so contaminated that the shallow wells have had in almost all cases to be abandoned, and the Thames and Lee waters are only available after repeated sand filtrations, with a final filtration through a large amount of animal charcoal.

The waters in the London district which can at present be safely used without filtration in the brewery are those supplied by the Kent and the New River Companies, and the waters obtained from the chalk, lying below the London clay and the sands associated with it ; the waters from these sands themselves are also sometimes available when they are free from iron.

Of the above present available sources the water supplied by the Kent Company is a pure chalk water, and the following analysis of the New River Company's water, which is also largely derived from the chalk formation, shows that it has the general characteristics of a pure chalk water, which for practical brewing purposes it may be considered to be.

Analysis of the New River Company's high pressure water supply :—

	Grs. per Gall.
Carbonates of lime and magnesia precipitated by boiling	11·2
Lime not precipitated by boiling	1·1
Magnesia not precipitated by boiling ..	0·2
Sulphuric acid	0·9
Chlorine	1·4
Nitric acid	0·4

or combined—

	Grs. per Gall.
Carbonates of lime and magnesia	11·2
Sulphate of lime	1·5
Chloride of calcium	1·4
Chloride of sodium	0·8
Nitrate of magnesia	0·6

The waters from the deep borings vary according to whether the latter are sunk in the Valley of the Thames or of the Lea, for while the former contain a considerable amount of carbonate of soda, the latter are almost, if not entirely, free from the carbonates of the alkalies.

The following are analysis of waters from these two sources. The first is the water from the deep well in one of the great London breweries, situated in the Thames Valley; and the second is the water from a boring at a well-known brewery in the Lea Valley.

Water from a deep London well in the Thames Valley:—

	Grs. per Gall.
Carbonates of lime and magnesia precipitated on boiling	4·9
Carbonates of the alkalies	13·0
Sulphuric acid	8·4
Chlorine	8·0

or combined—

Carbonates of lime and magnesia	4·9
Carbonates of the alkalies	13·0
Sulphates of the alkalies	14·4
Alkaline chlorides	13·9

Water from a brewing well in the Lee valley:—

	Grs. per Gall.
Carbonates of lime and magnesia precipitated on boiling	12·2
Lime not precipitated by boiling	0·7
Magnesia not precipitated by boiling ..	1·7
Sulphuric acid	2·4
Chlorine	1·6

or combined—

	Grs. per Gall.
Carbonates of lime and magnesia	12·2
Sulphate of line	1·7
Sulphate of magnesia	2·1
Chloride of magnesium	2·2

The identity in composition of the waters from deep borings into the chalk in the Thames valley is very remarkable. I have analyses of this water from borings near London bridge, and at various points up the valley, to within a few miles of Windsor. These analyses have been made at intervals during the last thirty years, and the results are so nearly the same in all cases, that they might very well be taken for analyses of the same spring. Waters of very much the same composition are also found in the same strata, as far west as Gosport, and nearly, if not quite as far east as Harwich.

These waters containing alkaline carbonates require treating in such a manner as to decompose the latter but I will postpone the consideration of the best method of doing so, until I come to the subject of treating waters. I will next allude to a very useful class ot brewing waters found in certain districts, generally near the sea coast, and containing large quantities of chlorides.

A well-known Yarmouth brewery has water of this class, containing an extraordinary quantity of chlorides, and it is notorious that when consumers become accustomed to the full rich flavour of ales brewed with such waters, they prefer them to all others.

A short time ago I was consulted by a north country firm of brewers, whose beers were very thin and poor in quality. They were brewing from a soft town water, but I found that they had a deep well in their yard, and on analysis this proved to be one of those waters

containing an abundance of chlorides. Some analyst utterly ignorant of practical brewing requirements, but none the less ready to pronounce decidedly on the matter on that account, had told them that it was too saline for brewing, but on my assuring them that this was a great mistake, they allowed me to brew from it. The improvement in their ales was of such a marked character that they added 50 per cent. to their trade. Of course I made many other improvements in both their plant and process, but I attribute my success in a great measure to the use of this brewing water, of which the following is my analysis:—

	Grs. per Gall.
Carbonates of lime and magnesia precipitated by boiling	7·0
Lime not precipitated by boiling	8·4
Magnesia not precipitated by boiling ..	4·6
Sulphuric acid	7·3
Chlorine	16·7
Nitric acid	4·6
or combined—	
Carbonates of lime and magnesia	7·0
Sulphate of lime	12·4
Chloride of calcium	6·4
Chloride of magnesium	6·7
Chloride of sodium	12·8
Nitrate of Magnesia	6·3

I have come across many brewing waters containing large quantities of chlorides, in both England, Scotland and Ireland, and provided that these waters were fairly free from organic impurities, I have nearly always found that the brewers using them were successful.

Having now given typical instances of the composition of the most remarkable of our brewing waters, I will next proceed to consider the relative action and importance of their constituents.

On comparing the foregoing analyses, it will be observed that there is one constituent which is present in all of them, viz., carbonate of lime, which is usually associated to a greater or less extent with carbonate of magnesia. These carbonates of the alkaline earths are held in solution in the water by the presence of an excess of carbonic acid, and probably in the form of bicarbonates. On boiling, this excess of carbonic acid is expelled from the water, and the earthy carbonates separate from it in a more or less crystalline form.

After boiling for one hour, only a trace of carbonate of lime remains in solution in the water, and the amount of that salt present in any water can, therefore, be always ascertained with the greatest accuracy. Carbonate of magnesia on the other hand, is much more soluble, and some of it frequently remains in solution even after long continued boiling.

I may here remark that those earthy carbonates which are rendered insoluble by boiling, constitute the temporary hardness of the older analysts. The degrees of temporary hardness are supposed to represent grains of carbonate of lime per gallon, and, in a rough sort of way they actually do so, but there are now methods so much more accurate, of determining the amount of the above carbonates present in any water, that in brewing water analyses the degrees of hardness may be safely omitted, and I myself only give them when specially requested to do so. Determining the hardness of a water is, however, a very simple process, and is sometimes useful in the brewery.

But to return to the effect of the presence of the carbonates of the alkaline earths in brewing waters; they are without doubt a most important and I think I may

even say an essential constituent. All really good brewing waters contain them, and in the few cases in which I have had to brew with waters in which they were not present, I have generally found it necessary to add one of them, before I could obtain satisfactory results.

The exact part which they play in the brewing process is not very accurately known. A considerable proportion of the carbonate of lime is always precipated when the water is boiled, and during this preciptation it carries down with it any iron that may be present in the water, and probably also other injurious impurities. A good deal of the carbonate of lime however, and a still larger proportion of any carbonate of magnesia that may be present, nearly always find their way into the mash tun, either in solution or in the form of a finely divided precipitate. In either case the lime and magnesia will combine with the acids always present in even the soundest malts, forming soluble salts principally lactates, and both the presence of these salts and the more or less complete neutralisation of the worts, must undoubtedly influence the subsequent processes, which the latter undergoes before it becomes beer.

The amount of the earthy carbonates present varies greatly in different brewing waters even of the same class, and within wide limits this variation appears to be of little consequence. I think that ten grains per gallon is a sufficient amount in all cases, and that anything less than four or five grains per gallon is not enough. I do not know that there is any proof that there is a distinct advantage in the presence of more than ten grains per gallon of earthy carbonates, but it is a fact, that some of the best brewing waters contain a far larger proportion.

Another essential constituent of all brewing waters is chlorine, which may be combined with either the alkaline metals, or with those of lime and magnesia.

I have already alluded to the marked advantage always derived from the presence of a sufficient amount of chlorides. Any brewer can ascertain the correctness of my views by adding the necessary chlorides to his brewing water, supposing of course that it does not contain them naturally, when the increase of palate fullness, and the general improvement of the ales, will prove sufficiently convincing.

It is certainly remarkable that the pure Burton waters contain only a small proportion of chlorides, but then the Burton ales when brewed from the pure water, are rather remarkable for delicacy than fullness. It is a curious fact, and one that strongly supports my views, that ales brewed from impure Burton waters, which contain large quantities of chlorides, are very much fuller than those brewed with the pure waters, although in other respects inferior, owing to the evil influence of the organic impurities.

Chalk waters also contain a very small amount of chlorides, but as most of the brewers using them add salt at some stage of the process, the general experience with these waters, also proves the correctness of my views.

The Dublin Grand Canal water contains a very minute quantity of chlorides, but as this water is used almost exclusively for black beers, it is scarcely a case in point, for although the presence of chlorides adds to the fullness of stout and porter, these salts are not so essential to the quality of black as of pale beers.

In asserting the value of chlorides in brewing waters,

I am enunciating no new doctrine, as most old brewers have great faith in the value of salt, I wish, however, to give some approach to scientific accuracy to this general opinion, and with a view of doing so I will go a little more into detail.

I think the best proportion of chlorides in a brewing water is represented by from ten to twenty grains of chlorine per gallon, and this chlorine should be combined with both the metals of the alkalies, and of lime and magnesia. The exact proportion of the various chlorides to one another may vary within considerable limits, but if the alkaline chlorides are about equal in quantity to the earthy chlorides, excellent results will be obtained, or in other words, if we have fifteen grains of chlorine present, about seven and a half grains should be combined with sodium and potassium, and an equal quantity with calcium and magnesium.

It is certain that chloride of sodium alone is not sufficient to produce the best results, and there is one very strong reason for adding chloride of calcium or magnesium, to a water naturally deficient in those salts, for by so doing the decomposition of the injurious carbonates and sulphates of the alkalies is insured.

The sulphates next claim our attention, and for the pale ale brewer their presence is generally considered to be essential. I do not think that I need enlarge on this point; the presence of sulphate of lime has been recognised as necessary by pale ale brewers, for the last forty or fifty years, and it is now upwards of twenty years since I first pointed out the necessity of adding the sulphate of magnesia also.

I have already shown that the proportion of the above sulphates in the best pure Burton brewing waters

is that represented by from eighteen to twenty-eight grains per gallon of sulphuric acid, and further that the relative proportion of these sulphates is one part of magnesia sulphate to three parts of lime sulphate, calculated as the anhydrous salts. If these proportions are not naturally present in his brewing water, the pale ale brewer should add enough of each to bring up the proportion to the above Burton standard.

A great deal has been written about the chemical effect of these sulphates on the wort, but very little is really known on the subject. In an article published in the *Country Brewers Gazette*, of January 22nd, 1879, I proved conclusively that these sulphates do not prevent the solution of the nitrogenous matters contained in the malt. I think, therefore, that I cannot do better than give this article as it certainly contains information of permanent interest to brewers. The following is the article in full as it originally appeared :

"It having appeared to me that the above subject has not hitherto received the attention that it deserves from chemists and scientific brewers, I have lately devoted a considerable amount of time and labour to carrying out the experiments required for its elucidation.

I now propose to place the results I have arrived at shortly before my readers ; but before doing so I think it will be well to note briefly what are the prevailing opinions on the subject, and also to define with some precision what, from a brewing point of view, constitutes a hard or soft water.

On page 56 of my treatise on "Brewing, practically and scientifically considered," I give the generally received theory in the following words : "These sulphates

remain in solution, exerting a most important chemical action upon the nitrogenous and extractive colouring matters of the malt, and in so doing affect that which is exceedingly desirable, and for the production of fine ales absolutely essential. Together with the precipitation of nitrogenous matter rendered insoluble by these salts, there is also the removal, or at least rendering insoluble, of certain constituents of the hops."

Again, in Mr. F. Faulkner's essay on "Rousing Fermentations," pages 3 and 4, he says, "Hard waters of the Burton type have but little extractive power, while soft waters generally are so very extractive, on account of certain saline contents contained therein, that by the use of such a solvent medium we find our worts are exceedingly rich in these albuminous matters which are contained in malt."

These quotations give, I think, a tolerably clear idea of the opinions generally held by those who have given any attention to the subject, viz.: That soft waters dissolve a much larger amount of certain substances, other than sugar, dextrine, and the products intermediate between them, than can be held in solution by hard waters such as those of Burton. The most important of these substances which are considered to be more soluble in soft than in hard waters, being the nitrogenous and colouring matters of the malt and certain intensely bitter principles of the hop.

Now, however universal the above opinions may be, I can discover no better foundation for them than mere conjecture, or, at the most, that reasoning from analogy which is answerable for such an enormous mass of error. My object, therefore, has been to ascertain, experimentally, what is the effect on the solubility of each of

the above substances of the presence of the sulphates of lime and magnesia.

This brings me to my second preliminary consideration, viz., What, from a brewing point of view, constitutes a hard or soft water? There are two varieties of hardness in water recognised by chemists—temporary hardness and permanent hardness. The former arises from the presence of the carbonates of the alkaline earths, especially of lime, held in solution by an excess of carbonic acid. When this carbonic is expelled by boiling, or otherwise removed, as by Clarke's process, the carbonate of lime becomes insoluble and subsides, the water at the same time losing its temporary hardness.

Carbonate of lime is a valuable constituent of brewing waters, but as it is precipitated by boiling, its effects extend but little, if at all, beyond the mashing process. It certainly purifies the water during its precipitation, and may neutralise some of the acids of the malt. Whether it has any further effects I am not at present prepared to say, but I hope at some future time to go fully into that subject.

Permanent hardness arises from the presence of certain salts which are not precipitated by boiling. The most important of these are the sulphates of lime and magnesia. These are the essential saline constituents of the Burton brewing waters, and it is to the consideration of their action that I at present propose to confine myself.

Soft waters are those which do not contain the above saline substances. Rain and distilled water are the most perfect types of the soft class, and in the present investigation I have used distilled water for all the soft

water experiments. Some soft waters contain alkaline carbonates, which still further increase their solvent powers; but the action of these must be left for a further special investigation.

Having now, I think, dwelt sufficiently on the considerations preliminary to my subject, I shall at once enter on its more important portion, including the results of the experiments I have carried out.

These experiments range themselves naturally under three heads, viz.: The effect of hard and soft waters on the constituents of boiled, but unhopped, malt wort; secondly, on those of the wort after it has been boiled with the hops; and, lastly, on the constituents of the finished beer. In the present article I shall confine my experiments and remarks to the first of the above.

Of those constituents of wort which are derived from malt, only, and which are supposed to be influenced by the hardness or softness of the water, most stress has generally been laid on the nitrogenous or albuminoid matters. I shall, therefore, commence with the determination of the exact influence of hard and soft waters on the proportion of these nitrogenous matters held in solution in the wort.

In the first series of experiments the hard water used contained the following saline constituents only: sulphate of lime, 55·7 grains per gallon, sulphate of magnesia, 13·8 grains per gallon. The soft water was pure distilled water.

I weighed out from the same bulk of pale malt which had been dried at a comparatively low temperature two exactly equal quantities. Each of these was ground tolerably fine, and mashed the one with the hard and the other with the soft water. Exactly the same

quantity of each water was taken, being in the proportion of two barrels per quarter of malt. The temperature of the mash in each case was 150° F., and both mashes were carefully maintained at that temperature for two hours.

The wort from each mash was then drawn off, and the goods equally mashed at the same temperature, in the one case with hard and in the other with soft water.

When wort equal to about five barrels per quarter had been drawn off from each, these worts were boiled for half an hour and allowed to cool while freely exposed to the air.

The two worts at this stage presented a remarkable difference in appearance, for while the soft water wort remained very cloudy, the hard water wort soon became bright, with a pure golden yellow colour. The precipitate from the latter also was in curdy flocks of considerable size, while that from the former was very finely divided, with but little flocculent appearance.

After the boiled worts were quite cold, they were filtered, and made up to the original bulk with pure distilled water. The hard water wort was now quite bright, but the soft water wort still remained rather cloudy. After standing in the cold for some hours, the soft water wort was filtered again, and now passed through tolerably clear, but with slightly more colour than the hard water wort.

As a slight deposit had in the meantime formed in the hard water wort, this was also filtered a second time, and the following determinations of the constituents were then made simultaneously; Hard water wort—total solids, dried at 212° F., 11·08 per cent. of the wort; nitrogen, 0·1073 per cent. of the wort. Soft water wort

—total solids, dried at 212° F., 10.64 per cent. of the wort; nitrogen, 0·1008 per cent. of the wort. As the hard water wort contained more solids, or in other words was slightly stronger, than the soft water wort, it was necessary to calculate from the above figures the per centage of nitrogen contained in the solids in each, so as to obtain a correct comparison between the two, and I thus found that the hard water wort solids contained 0·968 per cent. of nitrogen; the soft water wort solids contained 0·947 per cent. of nitrogen.

Multiplying the per centage of nitrogen in each case by 6·3—the usually accepted proportion being 1 of nitrogen in 6·3 of albuminoid matter—we find that, omitting fractions past the second place, the hard water wort solids contained 6·10 per cent. of nitrogenous matter; the soft water wort solids contained 5·97 per cent. of nitrogenous matter.

The difference between the above per centages is so small as to be of no practical importance, amounting, as it does, to only ·13 of a per cent. on six per cent.; but it is curious to note that the slight difference there is, is in exactly the opposite direction to what our pre-conceived notions would have led us to expect.

In a second series of experiments I used a very fine malt made by Messrs. Free & Hollis for Burton firms, and subjected on their patent kilns to a final temperature of 180° F.

The analysis of the hard water was as follows:—

	Grs. per Gall.
Total solid residue, dried at 212° F ..	116·20
Chlorine	1·22
Sulphuric acid	44·17
Nitric acid	none.
Carbonate of lime precipitated by boiling	12·95

	Grs. per Gall.
Lime combined with other acids than carbonic	24·49
Magnesia	4·86
Ammonia free .. 0·01 parts per million.	
Ammonia albuminoid 0·04 ,, ,,	

There was only a trace of discolouration on ignition of the solid residue.

The alkalinity of the boiled water arising from the presence of carbonate of magnesia, and perhaps minute quantities of an alkaline silicate, amounted to 2·22 grs. per gallon, calculated as anhydrous-carbonate of soda.

Distilled water, as before, was used as the soft water.

This second series was conducted in exactly the same manner as the first, and gave the following results :—

Boiled worts, after standing in the cold and in open flasks for eighteen hours.

Hard-water wort, bright near the surface. The matters rendered insoluble by boiling had separated in distinct curdy flocks, mostly non-adherent to the sides of the flask.

Soft-water wort cloudy throughout. The matters rendered insoluble by boiling were in the form of a non-flocculent precipitate, a great portion of which adhered to the sides of the flask.

Both worts were filtered and made up to the same bulk with pure distilled water.

Hard-water wort very bright and apparently a shade paler than the soft-water wort, which was, after filtration, still quite cloudy.

Both worts were allowed to stand in the cold for twenty-four hours longer, and then filtered a second time through dry filters. The first portions were collected

separately, and used to determine the colour and brilliancy, or cloudiness only, lest they might have taken up any impurities from the filters. The last half passing through the filters was taken for the determination of the nitrogen, solids and sugar, of which the following were the per centages found :—

The extracts per quarter, and also the solids dried at 212° F., were very nearly the same in both worts. This can rarely be secured even with the most careful manipulation, and, although not necessary in comparative experiments of this sort, is, to a certain extent, an advantage.

The extract from the malt in the case of the hard-water mash was 92·4 lbs. per quarter; the soft-water mash was 92·0 lbs. per quarter; hard-water wort, total solids dried at 212° F., 11·56 per cent. of the wort; nitrogen, 0·0994 per cent. of the wort; soft-water wort, total solids dried at 212° F., 11·52 per cent. of the wort; nitrogen, 0·1036 per cent. of the wort; and calculating, as in the first series, the per-centage of nitrogen contained in the solids, we find the hard-water wort solids contained 0·860 per cent. of nitrogen; the soft-water wort solids contained 0·899 per cent. of nitrogen. Multiplying the per centage of nitrogen in each case by 6·3, we find that the hard-water wort solids contained 5·42 per cent. of nitrogenous matters; the soft-water wort solids contained 5·66 per cent. of nitrogenous matters.

In this case we find a difference of ·24 of a per cent. on 5½ per cent. in the opposite direction to what we found in the first series. The hard-water solids thus contain a shade less nitrogenous matter than the soft-water solids; but the difference is so slight as to be of

no practical importance; and it is possible that it is caused in this last case by the presence of carbonate of lime in the water, of which there was none in the hard-water of the first series. It is interesting to note the effect of the high temperature to which the malt used in the second series was subjected on the kiln, resulting in the average reduction of the nitrogenous matter from 6 to 5½ per cent.

I also determined the amount of sugar in each of the worts, which I found to be, in the hard-water wort, 5·98 per cent.; in the soft-water wort, 5·97 per cent.

The analysis of the dry solids of each wort may, therefore, be stated to be as follows:—

	Hard water.	Soft water.	
Sugar	51·73	51·82	per cent.
Dextrine extractive matters and saline ingredients ..	42·85	42·52	,, ,,
Nitrogenous matters ..	5·42	5·66	,, ,,
	100·00	100·00	

The character of the water has, therefore, no appreciable influence on the amount of sugar produced from the malt.

A general review of the foregoing experiments proves, I think, conclusively that the sulphates of lime and magnesia, even when present in the brewing water in very large proportions, have no appreciable effect on the solubility of the nitrogenous matters, or, in fact, of any of the other constituents of the malt while in the state of wort, except, perhaps, on the colouring matters, which seem to be slightly more soluble in the soft than in the hard water.

The effect of the sulphates of lime and magnesia—in the earliest stage of brewing operations, at any rate

—is to greatly facilitate the ultimate fining of the beer, by causing those matters which are rendered insoluble by boiling to separate in a flocculent form, instead of in that minute state of division which results in the beer remaining obstinately cloudy, as so many brewers find to their cost.

Besides this most important property of these sulphates, they possess another which is almost equally valuable, but which analysis does not demonstrate. I allude to their slight but distinct antiseptic action. This may be easily ascertained by keeping flasks of hard and soft-water worts prepared as above, under exactly similar conditions, when it will be found that the hard-water wort resists the action of the fermentative germs for a longer period than that made with soft water."

This article proves clearly enough what the sulphates do not accomplish, and it also shows that they assist in both fining and preserving the wort, but there is another effect which is due to their presence, and which although somewhat difficult to prove by analysis, is at once recognised by the palate. I allude to their action in preventing the solution of the coarser bitter principles of the hop.

This property is very valuable to the pale ale brewer, for it enables him to use a large proportion of hops without rendering his ales excessively bitter. The presence of this large proportion of hop has two principal effects, for on the one hand its preservative and antiseptic action is very powerful, and on the other hand it gives that rich and full aroma which is characteristic of first-class pale ales.

Although the above sulphates are so valuable to the pale ale brewer, and when present in a smaller proportion

greatly improve the quality of mild ales, they are absolutely injurious in brewing black beers, if present to the extent of more than two or three grains per gallon.

I next come to the consideration of those salts which injuriously affect the quality of malt liquors, when present in the waters from which they are brewed.

The most important of these are the sulphates and carbonates of the alkalies, and iron in all its combinations.

I think that there can be no doubt that the sulphates of the alkalies, have a tendency to cause thinness of palate, and a peculiarly poor, and at the same time harsh flavour in ales. It has been also said that they prevent the ales fining, but I have never been able to find any proof of this assertion.

Their influence, however, on the flavour of the ales, is sufficient to render their presence in brewing waters very objectionable.

The presence of the carbonates of the alkalies has an even more injurious effect on ales, for these salts promote the solution of the colouring matters of both the malt and hops, and also of the coarse resinous bitter principles of the latter.

Neither of these salts is so objectionable in black beers as in ales, and some have asserted that waters for brewing stout and porter ought to contain a small proportion of the alkaline carbonates. This, however, is a mistake, as the best waters for brewing black beers are those which contain only carbonates of lime and magnesia, together with some chlorides, and minute amounts of earthy sulphates and alkaline silicates. All that can be said with truth is, that the alkaline carbonates are not very injurious in the case of black beers, although fatal to the quality of ales. The reason for their

comparative harmlessness in the brewing of stout and porter appears to be that they are to a great extent neutralised by the acids which are always present in black malts; and also that their solvent action on the colouring matters is an advantage in these beers.

Fortunately, when treating waters containing sulphates and carbonates of the alkalies for ale brewing, these salts are easily decomposed by the addition of chloride of calcium. On adding the latter, the alkaline sulphates become alkaline chlorides, the sulphuric acid combining with the lime, so, that instead of the injurious sulphates of soda and potassa, there remain in the water the chlorides of sodium and potassium, and sulphate of lime. The carbonates of the alkalies are decomposed by the action of chloride of calcium, into chloride of sodium and potassium and carbonate of lime, so that in both cases useful salts are produced from the injurious ones naturally present in the water. In some cases it may be advisable to add chloride of magnesium as well as chloride of calcium, but the latter salt is generally all that is required. I have mentioned already that it is always advisable to have some chloride of calcium in a brewing water, and one reason for this will now be manifest to the reader, for in its presence neither the injurious carbonates or sulphates of the alkalies can exist, so that it is a safeguard against their intrusion from any source.

The other injurious substance found in brewing waters, and of purely mineral origin, is iron in its various combinations. Iron is very injurious, as it precipitates the valuable principles of the hops, or prevents their solution. Every trace of iron should therefore be precipitated from a brewing water before it enters the mash tun.

If a fair proportion of carbonate of lime is present in the water the iron is entirely precipitated on boiling together with a portion of the carbonate of lime.

If the water does not naturally contain carbonate of lime, a little powdered chalk must be added to it, or still better carbonate of soda at the rate of about five or six grains to the gallon, and then an excess of chloride of calcium. It is not generally necessary to boil the water for more than ten minutes, but after ebullition the precipitate must be allowed to subside, and only the clear water must be used.

It is in the not uncommon case of the presence of iron in a brewing water, which is otherwise pure and of good quality, that the arrangement of hot liquor backs I have described in Chapter V. becomes advisable. If this arrangement is adopted, the water is boiled in the upper hot liquor back, and after the iron precipitate has subsided, it is run off free from sediment, into the hot liquor back or backs that supply the mash tuns. This is the most convenient arrangement, but the same object may be attained, by having two or more cocks in a single hot liquor back, one at the bottom for running off the precipitated sludge, and one or more inserted a few inches up the side of the back, to supply the brewing water free from sediment.

Of course other injurious mineral matters may find their way from dye works, factories, mines, &c., into brewing waters but these exceptional cases must be dealt with specially as they arise.

We have next to consider the organic impurities which pollute many otherwise excellent brewing waters, and also their oxidized products, which make their appearance chiefly in the form of nitrates and nitrites.

Organic matters whether of vegetable or animal origin consist, as far as we are now interested in them, of carbon combined with hydrogen and oxygen only, or of those elements combined also with nitrogen. These substances find their way into brewing and other waters, usually in an active state of putrifaction, having their source either in leaky sewers and cesspools, in dung heaps, in masses of dead leaves and other vegetable refuse, or in the decomposing bodies in burial places whether of man or animals. Sometimes also urinals discharging into leaky drains, introduce urea in an undecomposed condition, into the water.

The analytical detection of these organic impurities is now insured by the three following processes :—

1st.—The ammonia process discovers and estimates the nitrogenous mattters present in a more or less decomposed state.

2nd.—The oxygen process determines the amount of oxidizable matters present, and insures the detection of the urea from fresh urine, which is not disclosed by the ammonia process. And finally the amount of blackening, and general deportment of the solid residue on ignition, demonstrates whether any considerable amount of carbohydrates is present.

The nitrogenous organic impurities in waters, decompose after time, and the final result of this decomposition, is generally the formation of either nitrates and nitrites, or of ammoniacal salts, according to the amount of oxygen which has access to the water while the decomposition is proceeding.

Under the most favourable circumstances, however, the decomposition may be complete, when instead of the above products being formed, the organic substances are

resolved either into their elements, or into the simplest combinations of the latter. The resulting products are then carbonic acid, water, and nitrogen, which are, of course, perfectly innocuous.

It is this perfect decomposition which we endeavour to effect by means of filtration through sand beds, as carried out by the great water companies, or by the intenser action of animal charcoal, when the filtration is effected in the brewery itself. In this case, a true combustion occurs, as the oxygen, adhering to the grains of sand, or existing in the pores of the char, absolutely burns up the organic matters, leaving only innocuous products.

In certain waters, and specially those existing under the London clay, a very perfect filtration through immense tracts of sand and chalk, but in the presence of only a very limited supply of oxygen, has removed all the carbohydrates, but has only reduced the nitrogenous constituents to the form of ammonia, combined with carbonic or other acids. In this case also, the decomposition of the organic impurities has been carried far enough to render them innocuous, and the brewer, when using these waters, has only to make allowance for the stimulating effect of the ammoniacal salts on the yeast.

When the organic matter has not been decomposed in either of the above ways, it must either still exist in a decomposing state in the water, or it must have been converted into nitrites and nitrates. In both these forms it is excessively injurious, but in different ways.

When organic matter still exists in the water in a decomposing state, it is generally spoken of as recent organic matter, and in that condition it has exactly the

same effect on the beers as rotten corns in the malt, or mouldy hops, or filth in the pipes or plant, that is to say, it lowers the stability of the beer, inclines it to fret when new, and causes it to turn quickly acid on keeping. The higher the temperature the more rapid and intense are these injurious changes in the beer. In winter comparatively little damage is done, provided the amount of organic matter present is not very excessive, but as soon as the warm weather sets in the beers "kick up," refuse to fine, and soon turn sour and become undrinkable.

Nitrates and nitrites affect the beers in a totally different manner from the above. They do not cause them to become sour, but they act on the yeast, lowering its vitality, and promoting the growth of minute organism, probably micrococci. Under the influence of these salts the beers often assume a reddish opalescent appearance, with a flat unpleasant taste, and unless frequent changes of yeast are resorted to and obtained from some brewery where the water is free from nitrates, the deterioration proceeds until the beers will not attenuate sufficiently, and become mawkish, unpalatable, and practically unsaleable.

There is no known way of getting rid of nitrates when they are once present in a water; spongy iron filters have been proposed for the purpose, but I have proved them to be useless. The only plan is to change the yeast frequently, and as soon as the slightest appearance of anything wrong is observed. Filtration as I have said, has no effect on nitrates, but on the other hand it converts nitrites into nitrates, and is to that extent useful when the former very injurious salts are present.

Recent organic matters can always be removed by

filtration through well constructed animal charcoal filters, but if large quantities of this impurity are present the char must be frequently changed. No filtering material can possibly maintain its active properties for more than a limited period, and those filter makers who assert that their filters will maintain their activity for an unlimited time, without a renewal of the filtering medium, prove by such erroneous assertions that they know nothing of the first principles of effective filtration.

I have now had some ten years experience of Rawlings' patent animal charcoal filters, charged with his purified char, and by their means I have succeeded in purifying waters containing large amounts of sewage, and in brewing excellent beers with the purified water.

When animal charcoal is used for purifying water great care is required in the preparation of that filtering medium in order to render it thoroughly effective. The ordinary char of commerce is loaded with injurious impurities, and these have to be carefully removed by washing and reburning with special precautions before the char is fit for water purification. It is the neglect of this precaution which has so frequently led to the failure of this method of purifying water.

In order to guide brewers in the interpretation of the results of the determination of the organic impurities in water I may say that, according to my experience, no water can be expected to brew sound beer unless it complies with the following requirements.

The albuminoid ammonia in a water of first-class purity should not exceed 0·05 parts per million, and no water is safe for brewing even running ales during the summer if the albuminoid ammonia exceeds 0·10 parts

per million. These are the outside limits, and mischief not unfrequently arises before they are reached.

The free ammonia is of no importance in itself, but in waters from shallow wells it generally indicates the presence of injurious organic impurities if it exceeds 0·10 parts per million.

The oxygen required to completely oxidize any water should not exceed 0·05 parts per 100,000 of water, and in waters of first-class purity it should only amount to about half that proportion. The presence of iron and of nitrates interferes with the results of this test.

The blackening on ignition of the solid residue must not exceed a mere shade of colour. This test is not reliable when nitrates are present, for when a water contains a small quantity of recent organic matter, and of nitrates, these frequently decompose one another in such a way, that no blackening whatever occurs. Red fumes are however generally given off under these circumstances.

Nitrites even in very small quantities indicate that active decomposition is going on in the water, which cannot therefore be considered fit for brewing without filtration.

Nitrates when present in a smaller proportion than that represented by two grains of nitric acid per gallon, have no appreciably injurious effect, and even when the analysis shows the presence of less than five grains per gallon comparatively little trouble generally arises from this source. When, however, the latter amount is considerably exceeded the difficulties of the brewer become serious, and more especially if he has to produce fine pale ales from such a water.

To sum up this important portion of my subject. A

brewing water should be as free as possible from recent organic matter, and if it contains this impurity it should be filtered through properly prepared animal charcoal contained in a well constructed filter.

If the water contains nitrates these cannot be removed, and if possible a water free from these impurities should be obtained, but failing this, arrangements must be made to procure changes of yeast from a brewery using a water free from nitrates, as often as any yeast deterioration makes its appearance.

As regards mineral matters. The best waters for brewing stout and porter are those containing a fair amount of the carbonates of lime and magnesia, together with some chlorides, but they should not contain any large quantities of sulphates.

For ales of all qualities, the water should contain both the carbonates and sulphates of lime and magnesia, and also the chlorides of the metals of those alkaline earths, as well as the chlorides of sodium and potassium.

For mild ales the chlorides should be in excess, and should be present to an extent represented by about fifteen grains per gallon of chlorine. The sulphates for these ales are not required to an extent of more than five or six grains per gallon, provided there is the above proportion of chlorides. The presence of a larger proportion of sulphates however does no harm.

For pale ales there should be sulphates present to an extent represented by twenty grains per gallon of sulphuric acid, which should be so combined, that the proportion of lime sulphate to magnesia sulphate is about, three parts of the former, to one of the latter. A large proportion of chlorides is not injurious in pale ale brewing waters, but it is not essential; a proportion

represented by about three grains of chlorine is all that is present in some of the best Burton waters.

All the above mineral matters can be added to brewing waters, without the slightest difficulty either directly, or by double decomposition.

The injurious mineral matters usually found in brewing waters are the sulphates and carbonates of the alkalies, and iron in all its combinations. The latter is precipitated on boiling provided carbonate of lime is present in the water. The sulphates and carbonates of the alkalies, are changed by double decomposition into sulphates and carbonates of lime, on the addition of chloride of calcium, the chlorine combining with the alkaline metal. The above injurious substances, are not so injurious to black beers as to ales, and carbonates of soda and potassa can scarcely be said to be at all injurious to the former.

As regards the best form, in which to add the necessary mineral matters to waters in which they are deficient. Sulphate of lime may be added either in the form of a fine powder, or by passing the water through a vessel containing it in lumps. Sulphate of lime is also added to the water by double decomposition, when chloride of calcium is added to a water containing sulphates of the alkalies or of magnesia. When sulphate of lime is added in powder, care must be taken, either by maintaining a brisk ebullition, or by rousing, to keep it in suspension for about a quarter of an hour, so as to give it time to dissolve, and it must be so added as to ensure its thorough admixture with the water. Sulphate of magnesia is added in the form of crystals which are very soluble.

Chloride of Calcium. The usual preparations of this

salt are very troublesome to keep and to handle, but I have overcome this difficulty and now prepare a pure and very concentrated solution, which can be added to the water with the greatest ease, one pint being generally sufficient for ten barrels of water.

In breweries so constructed that it is difficult to add the necessary salts to the water, all of them except chloride of calcium can be added in the form of dry powder to the ground malt in the grist case but their addition to the water is the more scientific method of proceeding. Chloride of calcium solution may when necessary be diluted with water and added in the mash tun during the mashing process.

CHAPTER XV.

MALT & OTHER EXTRACT PRODUCING MATERIALS.

As water may be considered the most important constituent of beer, from its constituting the greater portion of its bulk, so malt may be looked upon as the most important material used in brewing, because from it are derived the nutritious and stimulating constituents, which give beers their great, and generally acknowledged dietetic value. This appears to be recognised by the popular term of "malt liquor," which is applied to all varieties of that beverage.

Malt may be produced from any of the cereals by the natural process of germination, checked at the appropriate stage, but barley is the only grain which combines in itself all the requisites for the production of a complete and perfect malt. I shall, however, include under this head all those preparations of grain, which, when mashed in various proportions with fine pale barley malt, yield a wort capable of producing malt liquors of first-rate quality, and containing all the ingredients which characterise a beer brewed from pale barley malt only. These preparations, although not

containing diastase, may still, I think, be fairly described as malts, just as blown or black malts have always been so called, although equally deficient in that substance.

Although I do not intend in these pages to go fully into the details of the malting process, I must dwell somewhat on those qualities which constitute a sound grain or malt, and on the circumstances which militate against that perfect soundness which is so essential in all brewing materials. It may be taken as an axiom that a first-class pale barley malt, containing its full proportion of diastase, can only be produced from a barley that has been evenly and perfectly ripened, and every grain of which yields, when broken, a floury mass, as free as possible from horny particles.

If the barley has been unevenly ripened some of the grains will germinate more rapidly than others, and where a proportion of them have sprouted in the field, or before the barley has been safely stored, their vitality will have been lost, and instead of germinating during the process of malting, they will form a fertile soil for the growth of acid and putrid ferments and of moulds. This will also be the case if the grains have lost their vitality from any other cause.

These dead corns must always prove to the brewer a most serious source of mischief, and that for three principal reasons. In the first place the diastase in dead corns is either entirely destroyed or its power is greatly reduced. In the second place these corns are full of acid and putrid ferments and of moulds, and also of the germs of those organisms. And thirdly, the nitrogenous matters in such corns have been changed under the influence of the above organisms, and have become putrid. In this condition these nitrogenous matters

form the favourite food of the disease ferments, instead of constituting a wholesome nourishment for the yeast cells, which is their function when in a sound and healthy state.

I look upon this putrid change in the nitrogenous matters as the most serious of all defects in malt. Careful mashing, and suitable heats both of mash and sparge, will prevent injurious results arising, from deficient diastatic power. Boiling and antiseptics will generally destroy objectionable organisms; but if putrid matters are dissolved in the wort, the organisms which feed on these matters, will inevitably make their appearance in the finished beers sooner or later, and especially those Bacilli which cause the development of lactic and other acids. Even before these acids make their appearance, the beers frequently get into a state of "fret," and although they may drop bright under the influence of finings, they become thick and cloudy again, sometimes even in the course of a few hours. The result is that such beers are undrinkable when new, as they will not remain bright even for a few days, and after being kept for a short time they turn acid and become worthless.

There is no practical method of getting rid of these putrid matters, when they are once dissolved in the wort, the brewer must therefore endeavour to exclude them, and to enable him to do this he must know from what sources they are derived.

The principal sources of putrid nitrogenous matters in beer are: first—the recent organic impurities in the brewing water which I have treated of in the last chapter. Secondly—mouldy and rotten corns, in barley and other grain, whether malted or unmalted. Thirdly—the putrid matters in many raw sugars and in mouldy hops. And

fourthly—decomposing wort, yeast, beer, &c., contained in, or adhering to pipes, vessels, and utensils, owing to neglect of cleanliness. It is only the second of these sources which we have now to consider, the first I have already disposed of, and the two last will be treated of in their proper places.

If the brewer will examine the individual corns of any sample of grain, whether malted or unmalted, he can soon ascertain the presence, and form an estimate of the number, of distinctly rotten corns in the sample. Their appearance alone will enable him to detect a large proportion of them, and the remainder will be manifest to his palate on biting them.

No malt or corn of any description can be depended upon to brew sound beers of good stability and keeping properties, which contains any appreciable number of rotten corns. For stock and export, anything over one per cent. should condemn the sample. Two or three per cent. is the outside that ought to be allowed in malts for good ordinary mild and bitter ales; but in cold weather, and for quick draught beers, a somewhat higher per centage will not produce any serious mischief, provided in this, as in all the above cases, there are no putrid matters in the beers derived from other sources.

Besides the presence of distinctly rotten corns, there are two conditions, which utterly unfit any corn for brewing purposes. The first of these is what is known as "weathering," and the second as "heating." Weathered corn is that which has been exposed in the field to an excessive amount of rain. The higher the temperature and the longer the time during which the corn is so exposed, the greater are the evil effects of the weathering. Weathered barley and other grain, has a dull colour and

in bad samples a blackish shade, by which the practised eye at once distinguishes it. Some rotten and also grown corns, will nearly always be found in such samples, but the weathering alone, independent of the more serious damage, will always produce a certain degradation, or deterioration of the nitrogenious matters which will be sure to cause "fret," and early acidity, in the beers brewed from such weathered samples.

Heated corn is that which, either in the stack, or when stored after thrashing, has passed through the condition which the term indicates. Heating always arises from the presence of an excessive amount of moisture in the grain, and without the presence of moisture heating is impossible; but storage in a large bulk, and in a warm, badly ventilated situation greatly promotes the mischief. The hold of a vessel therefore presents conditions which are highly favourable to the heating of all descriptions of grain, and brewers should always jealously inspect all cargoes arriving from foreign ports, before purchasing them.

In the great grain producing countries, such as America, enormous structures, called elevators, and fitted with powerful Jacob's ladders, are erected at convenient points, and if the grain in the hold of any vessel shows signs of heating, it is raised, and freely exposed to the air by means of these structures and machines, so as to allow the moisture to evaporate, and the grain to cool, when it is again consigned to the vessel's hold.

The heating of corn causes the deterioration of the nitrogenous matters, just as weathering does, although probably in a somewhat different manner. Heated and weathered corn are however certainly alike in one respect

for they are both of them equally incapable of producing a sound brewing material,—whether they are prepared for the mash tun by malting, or by any other process, even including roasting.

The peculiar smell of heated grain is quite unmistakable and is a sufficient indication of the existence of this form of mischief.

If a sample of grain is sufficiently free from sprouted and rotten corns, and is neither weathered nor heated, it can be prepared for the mash tun in various ways, so as to give sound results, but it does not follow that it can be grown on the floors, so as to produce a complete and perfect malt.

If grain is to be malted by the ordinary process of germination and kiln drying, and if a perfect malt is to be thus prepared from it, this result can only be secured by selecting barleys which are not only free from rotten and mouldy corns, and which are neither heated nor weathered, but which also possess certain special characteristics. In the first place, in order to secure the desired result, the barleys must be evenly and perfectly ripened, and in the second place, they must be of such varieties, and grown on such soils, and in such climates, as will enable them to appear, when broken, in the form of a floury mass. In fact, they must be what is technically called mellow, as well as sound, and perfectly ripened.

They must also be as free as possible from broken corns. This is a very important matter and unfortunately the modern thrashing machine, although a great economiser of labour, breaks far more corns than the old flail, so that broken corns are an evil which has greatly increased in modern times. It also chiefly affects the

best qualities of barley, and those which are harvested in the best condition, for the tenderer and dryer the barley is, the more liable it is to fracture when passing through the thrashing machine.

Broken corns are sure to become mouldy and rotten on the floors, and their presence to the extent of more than one per cent. must relegate even the finest sample of barley, to a very low class for malting purposes. A machine for effectually separating broken corns, is still a desideratum, and we must hope that our inventors will soon furnish us with one.

Barleys having the above qualities and free from the above defects, should always be prepared by germination, but there is only a comparatively limited supply of these first-class malting barleys, and it is far better to prepare the inferior qualities, and also those other cereals which can be used advantageously in brewing, by one of the other processes I have alluded to, and which I shall describe later on.

The process of malting by germination is no doubt the most advantageous of all processes, when applied to the proper qualities of barley, but with unsuitable varieties of grain, which do not grow freely, or as in the case of wheat and other naked grains, are liable to be injured, and to have the acrospire broken on the floors, it is far better to adopt other processes of preparation, and so avoid the unsoundness which is sure to arise from imperfect germination, and the mechanical injury of the corns during that process.

Barley Malt made by germination, and thorough kiln drying, from suitable qualities of barley, is, and will as far as I can judge always remain, the most important of this class of brewing materials. It is quite possible

that one third of the grist may hereafter consist of other preparations of grain, but even after the full development of new processes and systems, it seems most likely that about two-thirds of every mash will still consist of the old-fashioned barley malt, except where special mashing apparatus is employed, when the proportion of the latter may perhaps be reduced to one half. What then are the essential characteristics of this most important material? How should it be prepared so as to secure the best results, and how should it be stored so as to prevent its deterioration.

As I am not now writing a treatise on malting I shall only glance at the earlier stages of that process, and shall confine my remarks chiefly to the drying, curing, and storage of malt.

As far as my experience goes, the steeping and growth of malt on the floors is carried out in the vast majority of maltings in this country in a manner that leaves little room for improvement; but a very large proportion of the malt which has been thus carefully and successfully carried through the earlier and more delicate stages of its manufacture is seriously injured, if not spoilt, by the imperfect manner in which it is dried and cured, and by the carelessness with which it is stored.

There are, however, two or three points to which I wish to draw attention in the earlier stages; and I will begin with the preparation of the grain. In cold damp seasons and climates it frequently happens that some, of what ought to be the best malting barleys, never get thoroughly ripened, and consequently refuse to germinate evenly and kindly on the floors. It has been found by experience that this defect may be to a great

extent remedied by subjecting such partially ripened barley to a full summer heat for some hours on the kiln. Even well ripened barleys are improved by this treatment when it is necessary to malt them during the first two or three months after harvest.

Under the present system of collecting the Revenue, the screening out of the small corns is not so important as when the old malt duty was in force, but it is still very necessary to remove all dirt and rubbish, and also the broken corns as far as possible. For similar reasons in steeping I would insist upon the importance of thoroughly washing the grain while in the steep by means of a plentiful supply of fresh water, which should be as pure as possible. Experience seems to prove that it is of little importance whether hard or soft water is used for steeping, but whether hard or soft, it ought to be free from organic impurities.

On the floors most maltsters use more or less bisulphite in the sprinkling water, in order to prevent the growth of mould. In this they are no doubt right, but I think that a very dilute solution of salicylic acid might sometimes be substituted for the bisulphite with advantage, more particularly in warm weather. Some of my friends on the Continent inform me that they derive great advantage from the use of salicylic acid; and as it can do no harm, English maltsters should test its effects. It will probably be found advantageous to use bisulphite and salicylic acid alternately in the sprinkling waters.

How far the acrospire should be grown up the back of the corns is a question frequently asked, and on which there is considerable difference of opinion amongst practical men. All of them, however, I believe, agree that loss occurs when the acrospire comes through the

end, and few will dispute that a growth only half up the back is not sufficient. The correct point must, therefore, be between two-thirds and three-fourths up the back of the corn, and the nearer a uniform growth between those points can be secured the better. Before placing the malt on the kiln there is another point of great importance to be decided, and that is its state as regards moisture. Important as this question is, it can, I think, be disposed of in very few words, and I would say that the drier the malt is when placed on the kiln the better. Hence the advantage of withering; and a disregard of this essential consideration caused some heavy losses when the Galland system of automatic malting was first introduced.

I may here remark that this system of automatic malting has now been thoroughly tested in the United Kingdom, and as a manufacturing process it is certainly a success. For a number of seasons I have had the opportunity of examining the malts produced by Messrs. Perry, at their Roscrea Maltings, and I can speak in the highest terms of the quality of these "automatic" malts.

I cannot speak with equal confidence as to what would be the commercial results of the system, if generally adopted, but my opinion is that where a sufficient water power can be obtained, adjacent to any maltings, the automatic process will pay better than the old system, but that if an engine requiring constant supervision has to be kept going, simply to drive the exhausters or blowers, the old system, in this climate at any rate, and for barley malt, will still be found commercially the most profitable. One of the advantages claimed for the automatic process was that naked grains,

such as wheat, could be malted by it with less danger of injuring the acrospire, but under the present law, as I have already explained, these grains are best prepared by processes which do not involve germination.

When the malt is ready for the kiln, the further questions for consideration are: How much is it safe to put on a kiln of any given dimensions? For how long ought it to remain on the kiln? and To what temperatures ought it to be subjected while it is there? Now as regards the thickness of malt, which can be dried to the best advantage on any kiln, this almost entirely depends on the amount of draught, that is to say, on the ascensional force of the column of hot air, and this varies enormously in kilns of different construction. Thus seven or eight inches of green malt was as much as could be dried properly on one of the kilns formerly in vogue at Burton. These kilns were constructed with a perfectly open space below and of the full dimensions of the drying floor. The fire was in baskets placed at intervals on the floor of this space, and a large disperser was suspended above the fire baskets and about three feet below the drying floor. On the other hand, with Free's patent kilns a depth of fifteen inches of green malt may be dried and cured in the most perfect manner, and good results have been obtained with even eighteen or twenty inches. The saving in fuel on the patent kilns is also very large, amounting to from 40 to 50 per cent., but the most important point is that the work is better done, the malt being more perfectly dried and cured than was possible on any of the forms of kiln in use before Free introduced his improvements; in fact, owing to the construction of the majority of old kilns, it was impossible to dry off at a high heat without giving

colour to the malt, whereas with the powerful and rapid draught which can be obtained on the patent kilns the malt can be dried off perfectly pale at even the highest temperature at which malt can be cured without injuring the diastase.

Whatever kiln is employed the maltster must ascertain by experiment what depth can be perfectly dried and cured on it, and must strictly confine himself to that depth.

As regards the time required to dry malt, experience proves that the drying and curing cannot be properly accomplished under from three to four days, including the time required for loading and unloading. I am well aware of the common practice of only allowing two days; and on the continent, with double-floored kilns, even less time is often allowed, but the results are uniformly inferior. For lager beer, when the wort is made on the decoction process, a quickly-dried malt does not appear to be objectionable; the tedious but effective system of mashing making up for the imperfections of the malt. But with our simple mashing process we must have a malt so dried that the contents of each corn break down between the rolls into a fine flour; and this perfect "tenderness" of the malt, combined with perfect curing, requires a manipulation that does not allow of the kiln being loaded oftener than once every three to four days.

If the kiln is loaded at shorter intervals, one of two things must happen, viz., either sufficient time is not allowed for curing the malt, or else the earlier stages of the drying are pushed forward so fast that a tough, hard character is imparted to it. It is difficult to say which is the lesser of the above two evils; but it is extraordinary what a number of brewers throughout the country put

up with these evils, and the inferior character of the beer produced from malts dried in this imperfect manner, rather than erect kilns of such a size and construction as will secure uniformly good results.

Brewers now very generally recognise that a high final temperature on the kiln is required in order to impart that perfect soundness to the malt which is necessary, now that the public insist on their ales being free from acidity, but I find the views of the trade are still not sufficiently definite on this point. Many brewers and maltsters say to me, "We raise the temperature of our malts to 180°, 190°, or even to 200°, before taking them off the kiln," and yet I find these same malts not well cured. The fact is, that it is not merely a matter of temperature, but a matter of time also. For instance, a malt subjected to a steady temperature of 170° for twelve hours will be far better cured than a malt raised rapidy to 200°, and taken off the kiln directly the thermometer indicates the latter temperature. A similar mistake is often made in the earlier stages of the drying process, for many will allow the malt to remain for the first twenty-four hours on the kiln at a temperature not exceeding 90° F. This is a most serious mistake, as the malt is thus subjected for twenty-four hours to those temperatures which are most favourable to the growth of both moulds and bacteria. If the maltster will only bear in mind that a temperature of about 130° F, does not injure the diastase even in wet malt, and at the same time that that temperature at once stops the growth of all moulds and bacteria, he will see the necessity of bringing the whole load of the kiln up to 130° F, with as little delay as possible. When the malt is once up to 130° F., that

temperature must not be much exceeded until the bulk of the moisture is expelled, and the moisture should be reduced to about six or seven per cent. by the time the temperature reaches 140°. About three or four per cent. more of the moisture ought to be expelled by the time the temperature arrives at 155°, which should be when the kiln has been loaded for about 60 hours. Another twelve hours and the temperature should have risen to about 175° F., and then it should be maintained at from 175° to 185° for the following twelve hours, when the malt will be perfectly dried and cured, and can be at once removed from the kiln.

When the drying and curing process has been properly carried out, the moisture of the malt will not much exceed one per cent., and I place the outside limit at one and a half per cent. Any malt the moisture in which exceeds 1·5 per cent. when it is removed from the kiln has not been thoroughly dried and cured. Some of my friends who brew largely for export insist on their maltsters keeping the percentage of moisture below one per cent., and that this is practicable was proved last season when I determined for one brewer the moisture in every kiln of malt for many months with an average result of considerably less than one per cent.

I insist the more on the necessity for the perfect drying of malt, as the most absurd statements have appeared on this subject. For instance, in Hooper's little treatise, which is a compilation of a vast amount of information useful to brewers, he states that in thirteen samples of malt tested the lowest moisture was 3·8 per cent., and the highest 6·3, and hence deduces an average of 5·3 per cent., from which he infers that the moisture should not exceed five per cent.

This limit is far too high even for malts which have been kept in store for six months. If the store is a good one, and the malt was originally well dried, the moisture after six months storage will be less than three per cent., and even with indifferent storage it should not exceed four per cent. I am well aware that large quantities of malt are brewed in which the moisture amounts to five per cent., but I say that malts containing five per cent. of moisture rapidly deteriorate, and that excessive moisture in malt, although that moisture does not exceed five per cent., is the cause of unsoundness in large quantities of beer every year.

Of course, time is an important element in determining the soundness or otherwise of a malt with a given amount of moisture. Thus, if a well-dried and well-stored malt of the previous season is taken out of store in, say, October, and then contains three per cent. of moisture as it is filled into the sacks, the malt, after a long railway journey in moist weather, and the exposure in carting to and from the trucks, may very likely absorb another two per cent. of moisture; but if it is all mashed within the next fortnight, no evil results will arise, whereas if it had been transferred to the brewery store with five per cent. of moisture in it, and kept there for three months, the beers brewed from it would quickly tell what a serious deterioration the malt had undergone.

I will next point out what are the requisite conditions for storing malt so that it shall not deteriorate. These conditions, reduced to their simplest term, may be stated to be the exclusion of moisture from the malt. Dry your malt perfectly and exclude all moisture from it, and as far as our present knowledge extends, it will keep for ever without deterioration at the temperature of even

very hot climates. Now moisture enters the malt store either as the aqueous vapour which is always present in the air, or else by passing as moisture through the pores of the material of which the store is constructed. If brewers and maltsters will only keep the above facts in mind, and apply them intelligently when constructing their malt stores, they cannot go far wrong, for they will take such precautions as will render the sides of the store waterproof, and perfectly exclude the external air except when the store is opened for filling or emptying.

In Chapter VI. I have already described the methods of constructing malt stores, so as to secure the above objects.

Although long experience may enable experts to decide with tolerable accuracy, the value and quality of any sample of malt by mere inspection, a simple form of analysis, intelligently carried out, is a great assistance to even the best judges. By this means, the exact extract which any sample will yield may be ascertained with the greatest accuracy, and also the per centages of moisture and acidity which it contains.

A tolerably accurate idea of the stability of the beer that any malt is capable of producing, may also be arrived at by ascertaining the stability of the wort obtained from it; and if these results are supplemented by a careful examination of each individual corn, to the extent of one or two hundred, a more accurate opinion, as to the value of a sample can be given by anyone of moderate experience and judgment, than by the most experienced expert from mere inspection.

It is strange how few brewers avail themselves of this method of testing their malts. I think, probably, that many are deterred by the bad results obtained when they

have had samples tested by analysts, who either have had no personal experience in the selection of malts, or who leave all such work to assistants and pupils. Malt analyses are quite useless unless carried out by those who have had long practical experience in the selection and discrimination of malts, and who are prepared to devote themselves personally to such examinations.

The following are the characteristics of a first-class pale malt when examined and tested on my system.

(1) The malt must be evenly grown. The average length of the acrospire being between two-thirds and three-fourths up the back, and there must be but few corns in which it either pierces the end, or fails to extend to more than half up.

(2) The number of ungerminated corns must not exceed two per cent. The broken, damaged and mouldy corns must not collectively exceed two per cent., and these together with the ungerminated corns must not exceed three per cent. In other words there must be at least 97 per cent of perfect corns, all of which will break down at once into a floury mass, free from horny particles.

(3) Both the malt and the wort produced from it, must have a pleasant mellow taste, free on the one hand from rawness, and on the other from empyreumatic flavour.

(4) The rootlets must be of a uniform amber colour, not a mixture of white rootlets with chocolate coloured ones.

(5) The moisture, if the sample has been taken within a few days after the removal of the malt from the kiln, must not exceed one and a half per cent.; but in malts which have been stored for four months and

upwards, I do not consider double that per centage to be excessive.

(6) The acidity stated in terms of the amount of anhydrous carbonate of soda required to neutralise it, must be under one per thousand.

(7) The stability of the wort determined by placing it in Pasteur flasks with the usual precautions, must be such that when kept at 80° F, it does not break down in less than about eighteen hours.

(8) The extract may range from 85 to 95 lbs. per quarter, and the other characteristics being the same, the value of the malt will of course vary directly as the extract.

Under the above eight heads I have given as shortly as possible the characteristics of a first-class Pale Malt, but the subject is so important that I think I may with advantage enlarge a little further.

Taking the headings in the above order, I may say under No. 1, that the diastatic power in a malt increases in proportion to the length of the acrospire, probably reaching a maximum just before that organ pierces the end of the corn. If malt alone is to be used, the average growth should not exceed two-thirds, but a better result is generally obtained by an admixture of malt rather more fully grown, with a proportion of grain prepared by some process not involving germination. A malt grown to an excessive extent, and used alone gives a thin harsh flavoured beer. A malt too little grown gives a beer that is liable to fret.

Under No. 2 I have mentioned ungerminated corns, and horny particles in the germinated ones, as two serious defects. These together constitute steeliness, and although grinding a steely malt very finely, enables

the diastase to attack the malt more completely, and to convert the starch more perfectly in the mash tun, still as good results cannot be obtained from a steely malt, as from one which is free from this defect. When the steeliness arises from the presence of non-germinated corns, these are nearly always damaged to some extent in other respects, and their nitrogenous principles degraded, or even in a state of decomposition. This decomposition is greatly promoted by the heat and moisture to which these corns have been unavoidably subjected on the floors and during the early stages of kiln drying.

As regards the flavour of the malt and wort, my remarks apply to pale malts. Of course high dried and coloured malts have always a more or less empyreumatic flavour.

Under the 6th head I may remark that although an excess of acidity betokens unsoundness, the absence of acidity does not of itself involve the soundness of the sample. Many decidedly unsound samples are free from all excess of acidity, and many samples of raw wort become putrid, long before there is any marked increase in the amount of acid they contain.

In determining the stability of a wort, reliable results can only be obtained by strict attention to those details, which alone can insure the sterilisation of everything employed in the manipulations; and even then concordant results cannot always be obtained, as from the same bulk one sample may contain two or three mouldy corns, and another only one. On an average however it will be found that the wort from first-class sound malts does not break down until it has been in the hot closet for eighteen to twenty hours at 80° F.

Under my final or 8th heading I may remark that at least two corcordant determinations of the extract must be made, and these should agree within less than 1lb. per quarter. Malts of first-class quality may also yield less than 85lbs. per quarter, and in fact the finest Canadian barleys seldom yield more than 70lbs. per quarter. If the malt is first-class in all other respects, the value will vary directly as the extract, but the malts which only yield a small extract often produce the finest ales.

Few malts come up in all respects to the standard I have enunciated under the above eight heads, but for first-class stock and export ales, they must not fall far short of my requirements, or success cannot be insured. For beers which have not to be subjected to such severe tests, more or less inferior malts may be used with comparative safety, but those brewers, who tempted by cheapness, use malts which fall far below every standard of safety, must expect disastrous results.

There can be no doubt but that a large quantity of good barley, is every year spoilt by careless and ignorant manipulation, but there is an enormous bulk of barley now used for brewing, which although sound in itself, cannot by any treatment be made into sound malt on the germination system, and it is this class of barley which should be prepared by other methods.

The object of the new processes of preparing barley, wheat, and other cereals, the starch of which is convertible at the ordinary mashing temperature without previous boiling, is to prevent that hardening or vitrification of the grain, which always occurs when it is simply kiln dried.

Perfect kiln drying is essential in all cases, as un-kiln dried grain will seldom produce a sound wort, but it is

necessary to adopt some process which will prevent the grain becoming hard and horny, under the influence of heat.

My patented process of passing the moist grain through a roller mill of special construction, is perfectly effective, the crushed grain remaining floury and friable, even after having the whole of its moisture expelled, by exposure to an ultimate temperature of considerably over the boiling point. No colour is given to the grain by this process, even if the temperature is allowed to rise to 240°F, and perfectly sound worts are secured by the thorough drying and curing the grain undergoes.

There is another process of preparation known as the "Torrification" process, which effects the object of preventing the vitrification of the grain, but as the husk is always more or less burnt on this plan, an empyreumatic flavour is inevitably imparted to the wort, which is certainly objectionable in pale beers.

The advantage of using a proportion of grain prepared by my process is, that without deteriorating the quality of the wort, the dextrine per centage is increased, and with it the fulness, stability, and keeping properties of the beers. Of course the dextrine per centage may be increased by raising the mashing and sparging heats, but it is at the risk, or I may almost say the certainty, of the ales not fining well, and of all the evils arising from the presence of soluble starch in the worts. With my patent pale barley malt, prepared by the above process, low mashing and sparging heats may be used, and yet the largest advisable dextrine per centage secured. The wort is thus improved in quality and its cost reduced, the soundness, fullness and brilliancy of the beers being at the same time promoted.

There are certain grains such as maize and rice, the starch in which requires to be gelatinized, by being subjected to a temperature or about 200° F or upwards, before it is capable of complete conversion by the ordinary mashing process. In the case of these grains, the brewer's best plan is to erect special plant for their treatment, such as the Pigeon apparatus which is so much used by the American brewers.

In 1880 I patented the process of gelatinizing this class of grain, and then kiln drying it. This process was to a certain extent successful, but it is much more advantageous to erect special converting plant, than to attempt to use gelatinized grain in the mash tun. With a good converter the brewer can purchase his maize or rice in the open market, and thus secure for himself the whole profit of using a cheap and sound material.

Besides the pale malts to which I have so far confined my remarks, there are the coloured malts, the principal varieties of which are as follows.

Amber malt, which is simply pale malt that has been subjected to a high final temperature on the kiln so as to give it some colour, at the same time a portion of the diastase is destroyed.

Blown or brown malt, which is dried rapidly over a fire of beech or birch wood. This has a much higher colour than amber malt and contains but little, if any, diastase.

Black or patent malt. This malt is absolutely roasted like coffee, and the roasting should be so carried out as to produce the largest amount of soluble colouring matter.

Besides the above there is the so-called crystal malt, much used by some brewers. It is, I believe, prepared

by moistening the malt during the drying process with a solution of sugar, and then drying it off at a high temperature. Crystallized malt, therefore, may be regarded as a mixture of amber malt and caramel.

As I have already stated in my remarks on pale malts, soundness is greatly promoted by subjecting the malt to a high final temperature on the kiln, and of course the high temperature to which the coloured malts are subjected insures their soundness, provided they are produced from sound grain. It is, however, a most dangerous delusion to suppose that unsound can be converted into sound brewing material by the action of even a roasting temperature.

As an apt illustration of this point, I may mention that about two years ago, I came across several instances in which early acidity in black beers was distinctly traced to the black malt, which had no doubt been made from an excessively unsound barley.

In one of these cases, which was under my own observation throughout, I tested the matter thoroughly, by changing in succession all the brewing materials, but as long as I used the same black malt, all the porter and stout turned sour in a very short time. At last I obtained a supply of black malt from another maker, and the very first beer brewed with this new lot of black malt kept perfectly. I have gone somewhat fully into this matter as most brewers and maltsters are under the impression that black malt can be safely made from barleys however unsound they may be, and this mistake frequently leads to serious disasters.

Of course if in black malt, original unsoundness is not cured by a roasting temperature, it is evident that the much lower heat to which amber and brown malts

are subjected, cannot cure any unsoundness in the grain from which they are produced.

The soundness of the grain from which they are produced is, therefore, as essential in the case of coloured as in that of pale malts, but provided it is sound, and will germinate fairly well on the floors, but little more is necessary, at any rate for brown and black malts. Colour is manifestly of no importance, and even a certain amount of steeliness is not a serious drawback, as the high temperature is sure to break up the structure of the grain, and render it friable.

If a first-class amber malt, however, is required it must be made from a barley of good malting quality, and must be as well grown on the floors as if it was a pale malt, only a darker coloured barley may be used, and the heat increased more rapidly, and to a higher point during the last twelve or fourteen hours, that the malt remains on the kiln.

For ordinary beers a second-class amber malt will frequently answer well enough, and it is often convenient to make this by redrying old malt that has become somewhat slack by long keeping, or indifferent storage. This redrying of slack malt does not do away with the deterioration which has already taken place owing to the absorption of moisture, and consequent slackness, but it stops the mischief from proceeding further, and is so far of great value.

Amber malt is always dried on the ordinary malt kilns, and it was formerly the custom to dry brown malt also on ordinary kilns, with wire floors, but the labour on these was of a most disagreeable and exhausting character, and brown malt is now generally dried in wire cylinders.

Black malt is roasted in sheet-iron cylinders like coffee, but the malt is previously dried, more or less, on an ordinary kiln.

The best black malt is made by roasting malt of a fairly good quality, and the roasting must be very even and not carried too far. I strongly advise brewers to use only the best qualities of black malt, such as those produced by some of the well-known Dublin firms. These first-class black malts are in the end the most economical; and if the black malt is only good enough, the brewer will find but little necessity for using amber and brown malts, which, owing to the small extract they yield, are always expensive, while they give comparatively little colour, and are frequently of doubtful soundness.

Cheap black malts are frequently made by roasting barley and other cereals, but I cannot recommend brewers to use these cheap substitutes, which are nearly always disappointing, and not unfrequently lead to disaster. If, however, in seasons when good barleys are very scarce and dear a substitute must be found, sound maize well roasted, is enormously superior to black malts made from damaged barleys.

The following are the malts used for different qualities of malt liquor.

For pale ales, of course, only the palest malts can be used.

Mild ales are in most localities brewed of a higher colour than pale ales. When the requisite degree of colour can be obtained from malt dried at the ordinary temperature no coloured malt should be used, but when additional colour is required it may be obtained either by using amber malt, or a very much smaller quantity of black malt. For colouring ales really first-class black

malt answers, I think, better than amber, and gives less empyreumatic flavour, but inferior qualities of black malt should never be used for this purpose.

Porter and stout are brewed in Dublin from high-dried pale malt and black malt only, but London brewers generally prefer a grist containing all the three qualities of coloured malt, viz.: amber, brown, and black, in addition to the pale malt. In the case of black beers, as in that of high-coloured ales, I think that if the black malt is only good enough, the amber and brown may be dispensed with, and an additional amount of black substituted for them.

When black malt only is used in brewing porter and stout, one of black by measure, to seven of pale, is sufficient for the blackest beers, and one of black to twelve of pale is about the smallest proportion used, even in Ireland, where the black beers are generally far less highly coloured than in London.

I may here mention that there is a great advantage in using a proportion of wheat malt, prepared by my process, to replace some of the ordinary pale malt, in black beers. A proportion of about ten to twenty per cent. of wheat answers well, and promotes that fullness of palate, and permanent creamy head so much admired by consumers of stout and porter.

Having fully considered those substances from which the extract has to be obtained by the mashing process, I will next turn to those in which the extract is ready formed.

There is one substance of this latter class, which in former times was largely used by brewers, and probably, with satisfactory results, but which is now no longer available, I allude to honey, which in early times, was

a material much appreciated by private brewers, but the price of which, as compared with other substances, is now prohibitive.

The ready prepared extract producing brewing materials, which are now of practical importance, may be all classed under the three following heads, viz: Condensed wort, Glacose or sugar produced by the action of acids on starch, and Cane sugar with its Invert modification. I will consider these materials in the above order.

Condensed wort as its name implies is simply the wort produced by the ordinary mashing process, condensed or concentrated to any desired extent. In America and in the great continental brewing countries of Europe, this Condensed wort is largely used and highly appreciated, and it is generally supplied to the breweries in the form of a syrup, containing from 20 to 25 per cent. of moisture.

The Condensed wort manufactured in this country under my patent is supplied either as a syrup weighing 14lbs. to the gallon, and containing between 24 and 25 per cent. of moisture, or in a more concentrated form containing only about half the moisture existing in the 14lbs. syrup.

The materials employed in the manufacture of Condensed wort are sound malt and maize, the latter having been found after numerous and exhaustive experiments to be the cereal best adapted for the purpose. The manufacture or brewing of Condensed Wort is conducted as follows:—The malt and maize having been ground, the whole of the latter is mashed with a proportion of the malt into a jacketed mash tun, in which it is kept in constant agitation. The temperature is then raised to

such a point as to swell or burst the starch grains, the mash is then cooled to the temperature at which the diastase acts most vigorously, and more malt added. By these alternate heatings, coolings, and fresh additions of malt, the same effect is produced as by the German or decoction method of mashing, and a perfect conversion of the starch and peptonising of the albuminoid matters is effected.

The next process is to separate the wort from the mash, and this is effected by pressure, and in such a manner that a rich first wort is obtained, and also, a very valuable feeding cake which is consumed greedily by cattle, and almost all other animals. This cake possesses extraordinary feeding properties, for, owing to the perfect conversion of the starchy matters, and to the thorough peptonising of the albuminoids, every particle of the cake is rapidly digested and assimilated.

The great feeding value of this cake, pays a large proportion of the expenses of the manufacture of the Condensed wort, and thus enables the latter to be offered at a very moderate price to the trade.

But to return to the wort. After this is separated from the cake, it is boiled so as to precipitate the coagulable matters. It is then carefully filtered, and the pure wort finally concentrated in vacuo until it weighs exactly 14 lbs. per gallon, at 60° F. It then forms a permanent thick syrup, which never sets or crystallises, but can be always poured out of the vessel containing it. This syrup has a rich and very pleasant flavour, and can be made of any colour, from that of the palest malt wort, up to the colour of porter. It keeps well and is easily dissolved, in either the underback or copper. In the manufacture of the more concentrated or extra condensed wort it is kept in

the vacuum pan for a longer period so as to expel about half the remaining moisture and is then run into pails or bags.

It will be seen from the above details, that this wort is a true and perfect malt wort, that is to say, a wort produced by the action of the natural diastase of malt on the starchy ingredients of grain.

Condensed wort is, therefore, a perfect brewing material of the same composition as malt wort from fine sound malt.

Owing to the special mashing system adopted, the albuminoids are in a form specially adapted for nourishing the yeast, which is consequently rendered purer and more vigorous when Condensed wort is used. This is a very great advantage, and one that all brewers will appreciate more especially those who have suffered from that weakening of the yeast which always occurs when other sugars are used in any large proportion.

The sugars which come under my second head are all produced by the action of a mineral acid on starch. Sulphuric acid is generally used, and after it has converted the starch into sugar and dextrine, it is neutralized with chalk. The sulphate of lime is allowed to subside, and the weak syrup concentrated to some extent. It is then filtered through amimal charcoal and condensed in vacuo.

The sugars of this class imported from America are made from maize starch and when well prepared and refined they are of excellent quality.

The glucose which comes to us from the Continent is mostly made from potato starch, and although generally not equal to the best American glucose, is when well refined a good useful brewing material. Those samples

which are white in colour and perfectly free from unpleasant flavours, can be used with safety, but if there is any trace remaining of the flavouring matters derived from the potato, there is a serious risk of the flavour of the beers being injured.

The English made glucose is generally called saccharum, and when highly refined is like the American and Continental glucose a good brewing material. As however the price of pure starch is too high in this country to allow of its being employed, our manufacturers have to use either sago flour, rice, or maize. These materials are treated with sulphuric acid at a high temperature, and generally under a very considerable pressure, the result is that the sulphuric acid not only converts the starch into sugar, but also acts upon the albuminoid and fatty matters, producing from them substances with a most unpleasant flavour, and which unless removed are liable to spoil the beer.

The raw glucose solution is therefore filtered through large quantities of animal charcoal, and if this filtration is thorough and effectual a good and pure brewing material is produced; but I cannot advise brewers to use those dark coloured samples with an unpleasant bitter flavour, so often offered to the trade under various fine names.

The safe rule for the brewer is to use only those varieties of glucose, whether called saccharum or by any other name, which are either white or very pale yellow in colour, and which are quite free from bitter and other unpleasant flavours.

There is a liquid form of glucose known amongst other names as glucose syrup, which when well refined is a very good brewing material. It contains a considerable

per centage of dextrine which prevents its crystallizing and which renders it more suitable for brewing than the solid glucose. This syrup should be either colourless, or of a very pale straw colour, and quite free from bitter or unpleasant flavours.

Both the solid and liquid varieties of glucose usually contain from 18 to 23 per cent. of moisture, although I have met with some special qualities containing as little as 13 per cent.

Glucose, if pure, adds nothing but sugar, or sugar and a little dextrine, to the wort, only a small proportion of it should therefore be used. If a large per centage is employed, the yeast is weakened, and constant changes are necessary, and at the same time the nourishing properties of the beer are greatly diminished. A pleasant beverage may be produced but it has not the dietetic value of beer brewed from malt and corn only.

Under my third head, I include cane sugar, both raw and refined, and the invert sugar produced from it by treatment with sulphuric acid.

Raw sugars are all more or less liable to be contaminated with decomposing nitrogenous matters, fermentative germs, and other living organisms, both animal and vegetable. In the lower class of sugars, such as Jaggery, these impurities exist in large quantities, but even such qualities as fine crystallised Demerara are liable to be more or less contaminated with them. For this reason, raw sugars must always be regarded as dangerous brewing materials.

The reason of the liability of all raw sugars to the presence of the above objectionable substances and organisms, is that the cane juice being extracted, and the sugar prepared in a tropical atmosphere loaded with

germs, and at a temperature most favourable to their rapid development, decomposition often takes place before the sugar can be crystallised.

Raw sugars may be safely used in quick draught mild ale and porter, provided the yeast from them is rejected. For all other classes of beer the sugar ought to undergo some process of purification before it is used in brewing.

All cane sugars which have been thoroughly refined by filtration through animal charcoal are safe brewing materials, provided they contain no admixture of beet-root sugar. All sugars derived from beet, except absolutely pure white sugar, contain objectionable impurities, which char does not appear to have the power of removing. Of course an absolutely pure white sugar, whether in the form of loaf, or of large transparent crystals, is free from impurities, in spite of the source from which it may have been derived, but even those dry refined sugars known as "pieces," if derived from beet sugar, do not appear to be safe brewing materials. The rough and simple but effective tests are the taste and smell, and I advise brewers to reject all sugars which have the foul unpleasant odour and flavour which appear to always accompany sugars derived from beet, except in the case of pure loaf or crystals.

The lower products of the sugar refineries if free from beet, are safe brewing materials. The lowest class which are a mixture of syrup with crystals, and of much the same consistency as invert sugar, have a more or less treacly or empyreumatic flavour. These are well adapted for brewing black beers and for the cheapest running ales. The qualities known as "pieces" are dry sugars, and range in colour from yellow to nearly white: they can be safely used in all mild ales. The extract from

the above refined sugars ranges from about 75 lbs. to 85 lbs. per 224 lbs.

In dealing with all these cane sugars the brewer must remember that they cannot ferment until they have been changed by the action of invertin, or the soluble ferment contained in yeast. This invertin has the power of hydrating cane sugar, and thus converting it into fermentable sugars, just as diastase has the power of hydrating starch and converting it into sugar. I shall go more fully into the consideration of these soluble ferments in Part II, and only wish here to allude to them from a practical point of view.

As the yeast has to invert the sugar before it can cause it to ferment, it is generally supposed that this double call upon its powers weakens it. The evidence on this point does not appear to be at all conclusive, and in any case the increase if any in the amount of yeast required, when non-inverted cane sugars are used, is a matter which must be decided in the brewery. No exact rules can be given, but in this as in all other cases, each brewer must judge for himself, and test experimentally the amount of yeast required under the constantly varying circumstances which arise, always bearing in mind that cane sugars, whether inverted or not, weaken the yeast in the same manner as glucose.

There are numerous makers of invert cane sugar, and this article is very popular with most brewers. It ought to be prepared from cane sugar free from any admixture of beet. It is inverted by the action of sulphuric acid, which is afterwards neutralised, and the sugar is then refined more or less by char filtration.

The best qualities of invert sugar are excellent brewing materials for certain classes of beer provided they are

used in moderate proportions. Their most valuable property is that they enable the brewer to send out his running ales very much earlier than he otherwise could do. Running ales, brewed with twenty to twenty-five per cent. of invert sugar, can be sent out in brilliant condition within the week from the date of mashing, thus saving two or three days as compared with all malt beers, and economizing space in the brewery to a corresponding extent.

An excellent mixture for running ales required to be sent out at the earliest possible moment consists of seven quarters of malt, three cwt. of Condensed wort, and three cwt. of Invert Sugar; or if very rapid clarification is required, six quarters malt and four cwt. each of Condensed wort, and Invert sugar.

Even the latter proportion will give a yeast crop of good average strength, the condensed wort correcting the weakening effects of the Invert sugar on the yeast.

Both Condensed wort and Invert sugar possess another useful property when used in brewing beers which it is intended to export in bottle. Such beers if brewed from all malt have to be kept for nine months, or even longer before they are bottled, for if bottled earlier they throw down an objectionable amount of deposit.

If a proportion of Condensed wort, or of Invert sugar, or of both combined, is used, the beers may be bottled several months earlier, and yet will not throw down more deposit than the older beers brewed with all malt.

Some brewers now invert their own sugars, and the mere process of inversion is so simple that it can be carried out in any brewery. It is safest to invert refined sugars, but if certain precautions are adopted, even

raw sugars, provided they are of fairly good quality, may be inverted, and the product used without risk to the beers.

The ordinary process for inverting cane sugar is to dissolve one ton of the sugar in sufficient water to make the amount of syrup produced up to twenty barrels. Then add 12 lbs. of pure sulphuric acid previously diluted with three or four times its bulk of water. The whole is then boiled in a wooden tub, either by free steam, or what is far better, by means of a steam coil, for one hour. The acid is then neutralised by the addition of carbonate of lime, in the form of finely ground chalk. The sulphate of lime and other impurities are allowed to subside, and the clear syrup is then ready for use. The syrup left in the dregs may be recovered either by washing or filtration.

A better process is to use a mixture of sulphuric and sulphurous acids, for the latter not only inverts the sugar, but also bleaches it to some extent, and insures the destruction of all organisms. If this process is adopted six lbs. of pure sulphuric acid, and ten gallons of the ordinary five per cent. solution of sulphurous acid, are used to one ton of sugar, instead of twelve lbs. of sulphuric acid only. In all other respects the process is the same as that I have already given. The use of sulphurous acid is of special value for inverting raw sugars.

In either process if free steam is used, rather less water is employed in making the syrup. If on the other hand a coil is used the full proportion of water must be employed, and if the syrup becomes concentrated to less than twenty barrels, a sufficient amount of water must be added to keep it up to that bulk.

Having now fully described malt and the other extract

producing materials, the following is a short abstract of the conclusions we arrive at.

Malt made from first-class malting barley, and grown, dried, cured, and stored, in the most perfect manner, and then mashed, either alone or with a proportion of properly prepared barley, or other suitable grain, gives a wort and beer of the most perfect quality, and of the highest nutritive value.

Condensed wort, of sound quality and well prepared, can be conveniently substituted for a portion of the malt without injuring the quality or nutritive value of the beer.

The yeast crop from all the above materials is perfect in quality and strength.

Glucose, Cane sugar, and Inverted cane sugar, are convenient materials, and the latter aids the rapid and early clarification of the beer, but they all diminish the nutritive value of the beers in which they are used, and weaken the yeast crop. A proportion of Condensed wort used with these materials tends to maintain the strength of the yeast.

All the so called saccharums, malt sugars, etc., by whatever specious names they may be called, are either glucose, with a little dextrine, cane sugar, inverted cane sugar, or mixtures of these.

I will conclude this chapter with a simple rule for determining the extract value per 224 lbs. of any soluble extract yielding material. The apparatus necessary consists of scales which will stand a weight of about half a pound in each pan, and turn with one grain when so loaded; a set of weights or counterpoises, a cup of any sort holding about half a pint, in which the sample of sugar is weighed and dissolved; and finally, a glass tube

holding a little more than 6000 grain measures, and marked distinctly at that point.

The process is as follows :—

Place the cup on the balance and counterpoise it. Then place in it 1344 grains of the sample. Dissolve in water. Pour the solution into the glass tube. Rinse the cup into the tube repeatedly with water, and finally cool to 60° F., and make up to exactly the 6000 grain mark with water. Mix well the contents of the tube until of exactly the same density throughout. Now take the specific gravity with the ordinary excise instrument, and every degree on that instrument will represent 1 lb. per barrel of extract from 224 lbs. of the sample.

It may be interesting to know that exactly 217⅓ lbs. of absolutely pure cane sugar will give 85 lbs. of extract.

CHAPTER XVI.

HOPS.

THOSE brewers who are not immediately connected with the cultivation and management of hops, prior to their being cured, will probably hesitate to incur the additional risk of engaging themselves in this frequently highly profitable but hazardous business. The capital required for successful hop growing, however, may be taken on a general average to produce at least as good a commercial return as that invested in the production of any of the other materials required for brewing.

Neither the scientific nor practical aspects of hop production come within the scope of this work, but a few remarks are necessary to show the connection between the successful cultivation of the hop plant generally, the selection of the different kinds suitable for the various descriptions of beer, and also in their relations as regards economy and quality. In the cultivation of hops, scientific means have to be consulted to an extent surpassing perhaps that of any other agricultural operation. Premising that it is as hopeless to expect to obtain the best return of Goldings from those gardens where clay composes an important constituent of the soil

as it would be to plant Canterbury Grapes or Colegates on the sand and deep humus suitable for Goldings, we must not expect to obtain the same perfection of delicacy in quality in other varieties which the Golding hop combines with fulness of extract.

The early kind of hops—Meophams and Prolifics—possess a brilliancy which gives them a saleable value in spite of their general want of condition; on the other hand, those which come to maturity later in the year, including the Colegates, yield a harsh bitter, economical enough if mere bitterness were desirable, but which cannot compare with hops of the type of Goldings, whether produced in early, middle, or late season.

The Worcester hop, however, frequently equals the Golding in its finest properties especially during the earlier portion of the season, but it has not quite the same lasting properties as the latter, and is therefore more suitable for brewing up to the end of May, than during the summer months.

So long as brilliancy and paleness of colour are preferred to the more sterling qualities, so long will the finest brewing value in hops be frequently neglected. The overweening desire to follow in the footsteps of those who brew the most fashionable beers, sometimes continues after the first leaders of the mode have seen reason to hold back from the extremes to which others may erroneously attribute perfection. This is emphatically the case with regard to pale ale. Granted that pale ale was fashionable, and is still regarded as the highest class of this description of beer, something more is requisite than the quality of paleness. The most admired pale beers of Burton were for many years noticeable as containing less colour than other beers.

In the spirit of competition, the palest malt and hops have been run after until the pale ales of Burton are transcended in this particular by the paler ales of other localities. The highest quality of ale is rarely attainable by the use of such materials as malt and hops when unduly free from colour, and economy must be altogether disregarded, when it is attempted to use thin, weak, but light and brilliant hops, which, though commanding the best prices, contain so little condition that every full brewing quality is sacrificed to colour.

The strobules, or catkins, of hops, most suitable for brewing, should be full of seeds, full of farina, lupulin, or condition, and, when dry, a fine specimen of hops should yield fifteen or sixteen per cent. of these golden grains.

The lupulinic grains are, in reality, aromatic superficial glands upon the seed or nut; these are protected by scales, or bracts, which enclose them. The central depression, or hilum, which under the microscope has a dark or blackened aspect, is surrounded with the cellular formation. Within this cellular structure is contained the valuable hop oil, concerning which there is a general faith that the finer and more delicate aromatic properties of the hop almost entirely depend. How far this is absolutely true it would be difficult to closely define, and the difficulty is increased in consequence of the very poor advance which has yet been made towards ascertaining the nature of the components of the matters extracted from the hops during the process of brewing.

We are evidently at a disadvantage in endeavouring to compare the analysis of hops quoted from Payen, Chevallier, and Pelletan, so as to afford us any accurate notion of the constituents absorbed by beer from hops, either in the process ef brewing, or dry hopping. More-

over, a very serious discrepancy exists between the statements of the French chemists and those experiments undertaken by myself and others. For instance, Dr. Ives agrees in the proportion previously given, of the percentage of lupulinic grains contained in good samples of hops. But his analysis of these lupulinic grains attempts to estimate the tannin, the extractive, the bitter principle, the wax, resin, and lignin centesimally, and as the quantities of these components add up so as to show only a loss on working of ·02 per cent., it is plain that he did not attempt to isolate or take into account any volatile matters whatever. The essential oil of hops was, therefore, practically non-existent in his estimation of the components.

The three French chemists, again, analysing the lupulinic grains, find only two per cent. of volatile oil, together with the slightest traces of other fatty matters. On the other hand, Dr. Wagner distilled oil from fresh hops, and declares that he obtained eight per cent. from air-dried flowers. The volatile matter obtained by Dr. Wagner was probably of an extremely complex nature, bearing scarcely any relation to the volatile oil of hops extractible by brewing.

Dr. Wagner, in his observations, affords us some clue by which we can understand how he obtained so large an amount of volatile matter. He says: "It possesses a clear, brownish, yellow colour, and has a strong odour of hops and a slightly bitter taste analogous to thyme; its specific gravity is ·908, and it is very sparingly soluble in water, requiring more than 600 times its weight for solution. When rendered anhydrous by distillation over fused chloride of calcium, it partly evaporates at a temperature below the boiling point of water, and

commences to boil at 257°, rising to 347°, at which temperature nearly one-sixth of the clear oil distils over. The portion passing over between 347° and 437°, constituting one-half of the oil, was also clear, but that which passed over between 437° and 455° was of a yellow colour. The residue in the retort, about one-sixth of the quantity subjected to distillation, was brownish, and like turpentine."

Clearly we can have nothing to do with those matters which are insoluble in boiling water, or which will not evaporate except at these excessively high temperatures. In truth, a large proportion of what Dr. Wagner denominates volatile oil of hops must be of the nature of those hydrocarbon oils produced by the destructive distillation of almost all organic matters, whether recent or fossil. A parcel of bran would probably produce fully as large a percentage of the volatile matters coming over between 437° and 455°, as was obtained by this gentleman from the most fragrant specimen of new hops. It is well also to bear in mind that Payen and Chevallier declare that hop oil belongs to those "ethereal oils containing sulphur, and that it dissolves largely in water, and on this account preserves the beer."

Wagner and Von Bibra point out that it contains no sulphur, and is isomeric with camphor, bergamot, turpentine, and other oils, which on oxidation become resinous. The French chemists record their testimony in favour of the general belief that hop oil possesses strongly-marked narcotic properties. Wagner and Von Bibra made numberless experiments to ascertain whether oil of hops acted in this manner, and declared as emphatically that it had no such action. With such contradiction of authority introduced with almost all the more important papers and articles treating on hops

as applied to brewing, the quotations being placed almost in juxtaposition, and without any explanation of their contrary bearings, it is scarcely extraordinary that but little dependence has been placed upon any of the results so set forth.

Supposing that an exhaustive analysis of hops were made from the brightest and fullest sample of any one year, it might afford some standard for comparison with other analyses of hops if taken at different seasons. But the real tangible benefit to be derived from analytical research is not so much to ascertain the exact proportions of different constituents, although an approximation is doubtless desirable, as to determine the quality of the extract of hops derivable by a process precisely similar to that attained in brewing. My own experiments were conducted in the first instance for the purpose of estimating roughly the amount of true volatile oil obtainable from hops without destructive distillation. For this purpose I took a small retort of special construction, in which a weighed quantity of fresh hops was placed so that steam could be passed through them, and I connected this retort with a condenser drawn down to a fine aperture. This was adapted to a measuring apparatus, through which the condensed vapours were passed, bearing the oil floating on the surface of the water. After passing steam through the retort until it ceased to carry over any more oil, the measuring-tube was detached from the condenser, and the water allowed to fall until the oil itself came within the graduation of the instrument. By this means I have ascertained that rich samples of season hops yield rather more than two per cent. of their original weight, and that good yearlings, or what may be

termed average samples, generally contain about one and a half per cent. of oily matters capable of volatilising with steam at 212°. As compared with the estimation made by the French chemists, it will be seen that I obtain as much volatile oil from the commercial samples of hops as they have from the lupulinic grains alone. Now, as we are agreed that the lupulinic grains constitute only some fifteen or sixteen per cent. of the hops, it becomes evident that I invariably obtain from five to seven times as much volatile oil as was found by those gentlemen.

As I have shown, the estimation of the volatile matters from hops made by Drs. Wagner and Von Bibra is in excess of mine, which arises from their having included the products of destructive distillation. I am therefore disposed to believe that further experiments will corroborate the estimation I have given. It must be borne in mind that in distilling the mixture of substances termed lupulin with water, valerianic acid and a volatile oil of the nature of hydrocarbon is carried over, but the bitter principle of the hop or true lupulin is dissolved by digestion in water. On this point we have not that diversity of statement which characterised the preceding determinations. Payen and Chevallier find from eight to twelve per cent. of true bitter principle in crude lupulin, but my own experience leads me to believe that far more than twelve per cent. of the lupulin is composed of bitter extractive in certain coarse hops: perhaps five per cent. of pure bitter is as much as can fairly be accorded to the lupulin of the finest and most delicate varieties. The amount of the astringent principles of the tannin class may be taken as about two per cent.

Without considering the determination of sulphur in

hop oil of the slightest value to the brewer, it may be of some service to append two analyses of the ash of characteristic samples of hops by Dr. Bartlett, which will demonstrate the amount of sulphur compounds natural to the hop itself by the amount of sulphuric acid found. The presence of minute quantities of sulphur compounds must not therefore be accepted as being certainly due to sulphuring, either in the field or on the kiln.

	Goldings.	Canterbury Grape.
Potash	25·5	19·1
Soda		1·2
Lime	22·1	13·2
Magnesia	6·1	5·3
Oxide of Iron	1·3	2·1
Alumina		1·1
Sulphuric Acid	11·9	7·1
Silica	13·0	23·5
Phosphoric Acid	17·9	24·1
Chlorine	2·1	2·2

The contrast between the mineral constituents of these two kinds of hops must be due to the different nature of the soils on which they were grown.

Without laying much stress upon the sulphates of the alkaline earths which may be present, it is quite certain that the use of shoddy as a manure must always tend to increase the amount of sulphur compounds which are found in the hops on analysis.

When, as is frequently the case, coarse shoddy or "mungo" has been previously treated with sulphuric acid, we may anticipate combinations of sulphur in most of the proximate principles of the hop, and they may perhaps be detected without resorting to ultimate analysis.

Much has been said as to the evil effects of sulphuring hops, and many crude theories have been propounded

and assertions made, but little if at all supported by fact, concerning the mischiefs which ensue to the brewer from this source. It is advisable, therefore, to go carefully into this subject.

The sulphur is applied to hops under two very different conditions. In the first place, it is used as flowers of sulphur in its unoxidised form to prevent or destroy those dire enemies of the hop-grower, mildew and blight. Now, although it is conceivable that very minute quantities may be absorbed by the plant, it is impossible to imagine that this can take place to such an extent as to have the slightest effect on the beer brewed from the hops so treated. Small quantities may remain adherent to the hops, but as sulphur in its unoxidised form is insoluble, this can have no evil effect.

As, however, sulphur is only used when the hops at some period of their growth have been attacked by mildew or blight, any evidence of their having been sulphured during their growth must cause suspicion that mildew may still be present. Even if this is not the case, the germs may have been only rendered latent and not destroyed, and consequently they may reappear in the beer, in which case they would undoubtedly cause serious mischief.

It is most important to ascertain the absolute freedom from mildew of the hops used in the production of the higher class of ales. The experienced brewer can generally judge by the appearance of the hops of their condition in this respect. In a sample where a serious amount of mildew is present, portions can almost always be found in which the eye can clearly detect it. Where, however, the hops are required for the manufacture of the most delicate malt liquors, and especially where they

are to be largely used in dry hopping, it is well to supplement the general inspection of the sample by a minute microscopic examination.

All hops that have been in any way affected by mildew at any period of their growth must be considered to have been more or less seriously deteriorated. And as sulphur is not generally applied before the appearance of some form of disease renders it manifestly necessary, it may, I think, be safely maintained that any sample in which the presence of flowers of sulphur can be detected cannot be considered as of first-class quality; although, at the same time, I am confident that the sulphur itself can have no injurious effect on the beer.

Sulphur is also used during the process of the drying hops; it is then applied as sulphurous acid by burning small quantities on the fuel. When employed judiciously, and in very small quantities, especially if there is reason to suspect that the hops are affected by mildew or any other parasitic germs, sulphurous acid will undoubtedly have a most beneficial effect. The brewer should be the last man to deny this, considering the numerous advantages he has obtained by a well-regulated use of sulphurous acid in destroying false ferments in his beer. It is certainly more rational to destroy the germs of these false ferments in the materials where every sort of ferment is detrimental, than to attempt a discriminating destruction of the false ferments only, in the presence of the delicate yeast-plant, which is so easily killed by the slightest overdose of sulphurous acid.

The danger of sulphuring hops during drying is that in careless hands it may be so easily overdone, and that the temptation is to overdo it, as by this means the sample can be greatly improved in appearance, sul-

phurous acid having a powerful bleaching action, which produces a brightness and paleness of colour very pleasing to the eye, but of a most deceptive character.

The excessive application of sulphurous acid to the hops on the oast does away with all delicacy of aroma, and may, if carried beyond a certain point, impair or even char the hop oil, bitter principle and tannin, by the after production of free sulphuric acid.

A really fine sample of hops, absolutely free from mildew or other disease, requires no sulphur in any portion of its growth, or preparation for the market, and it is only such samples that can be rightly placed in the first class.

As, however, even in favourable years, a vast amount of mildew and other disease always exists in hop plantations, a judicious application of sulphur both during the period of growth and in the after stages of preparation, preserves an immense amount of valuable hops, and prevents prices from rising to a point which would be utterly ruinous to the brewing trade.

It must be clearly understood that if any trace of mildew or of other disease is present, a moderate use of sulphur at all stages is a clear gain to the brewer, saving a vast quantity of the crop in such a condition that it can safely be used for all beers, except the very finest ales. These same hops, if no sulphur had been applied, would, if they came into the market at all in a saleable form, be in such a state as to induce the most serious mischief and deterioration in all beers brewed from them, even those of the commonest quality.

It is therefore useless for the brewer to lay his troubles at the door of the sulphur used by the hop-growers, as he would be in a far worse position if they discontinued employing it. His object should be to bring all his

influence to bear on the prevention of the excessive use of this substance, by placing very low on his list those hops in which an unnatural paleness, or other fictitious appearance of value, has been produced by an undue use of sulphur.

The dressings and washes used by hop growers, other than sulphur and not including those dressings used as manure, have mostly for their object the destruction of the aphis during some period of its development and the prevention of the fearful ravages of that dreaded insect pest.

Miss E. A. Ormerod, consulting entomologist to the Royal Agricultural Society, in her "Report on Injurious Insects, for 1884," goes very fully into the results obtained by a careful series of experiments carried out under her direction, and the following are the conclusions she arrives at:—

"1. That the first attack of aphis to the hop begins in spring from wingless females (depositing living young), which come up from the hop-hills.

"2. That the great attack, which usually occurs in the form of "fly" about the end of May, comes on the wing from damson and sloe, as well as from hop, and that the hop aphis and the damson hop aphis are very slight varieties of one species, and so similar in habits as regards injury to hop that for all practical purposes they may be considered one.

"3. Further, it has been shown by the result of various experiments on the hop-ground at Stoke Edith Park, Hereford, that the use of various applications round the hills in the late autumn, or about the beginning of April in spring, completely prevented attack to the bines of those hills until the summer attack came on

the wing. Amongst these applications paraffin was especially noticeable, as the plants treated with it were reported throughout as thriving up to the point of bearing well; and the serviceableness of mineral oil, both as a preventive and remedy, has been confirmed by the reports of experiments regarding the use of petroleum and kerosine in dilute state, published by direction of the Department of Agriculture of the United States of America."

Several dressings were applied to a number of hop-hills, but those in which paraffin was the active ingredient were by far the most successful. Gas lime was found to be injurious to the hops, as were also salt and salt mixed with lime, in less degree. Lime alone and soot alone did good; but the application to be recommended is a mixture of one quart of paraffin with one bushel of ashes. Where ashes are not easily to be procured, sawdust or shoddy will do in the same proportion to paraffin. As a wash to be applied to the hop bines when attacked by aphis later in the season, Miss Ormerod recommends 12 lbs. of soap and half a gallon of paraffin to 100 gallons of hot water (the nearer to boiling the better), thoroughly mixed by well stirring the ingredients. This wash has been found very effective in destroying the insets without injuring the plant or burr. Other washes, some containing quassia, are also named as having been successfully used.

I would suggest, from a brewer's point of view, that although dressing the hills with paraffin oil (for it is evidently the oil and not the wax that is alluded to by Miss Ormerod) is not objectionable, and even applying a wash containing that liquid to the plants in the early stages of their growth may not injure the quality of the

hops, still that there is a point soon arrived at when the application of paraffin oil would be most injurious. I think this point is reached as soon as, or just before the time, when the burrs first make their appearance, for if these are once drenched with paraffin oil they will retain the obnoxious smell and flavour of that liquid, and impart it to the beers in which hops which have been so treated are used.

The wash of quassia and soft soap, at the rate of three ounces of each to a gallon of water destroys the aphis, and may be used up to a much later period than the paraffin wash; and pure water in which some quassia has been boiled, can be used without serious injury to the hops, as long as any washing whatever is permissable.

I must not conclude these remarks on the methods of destroying the aphides without reminding my readers of the debt of gratitude we owe to the natural enemies of those pests, viz., the ladybirds.

The judicious brewer who is desirous of extending his trade by giving his customers the best value compatible with a fair profit, must most carefully discriminate between the different qualities of hops, using those only which are best suited to each class of beer that he wishes to produce.

To use the most delicate new hops for the production of black beers is a manifest absurdity; but it is quite possible, without going to such an extreme, to spend a large amount of money without any corresponding result.

Long experience only can enable the brewer to carry this discriminating process to its greatest perfection; but I will lay down a few general rules which may prove of use.

Hops are added to the beer either in the copper, where

they are boiled for a longer or shorter period with it, or they are added to the finished beer after the close of the fermentation; in the latter case the operation is known as "dry hopping."

It is only of late years that the process of "dry hopping" has received some portion of that attention which its importance demands. In boiling hops, the more delicate and volatile portion of the essential oil is dissipated, and at the same time all attempts to produce good sound malt liquors without thorough boiling with the hops have proved utter failures. "Dry hopping" is, therefore, the only means of securing the presence of these highly volatile matters, and without them it is impossible to obtain that delicacy of flavour so much admired in the Burton ale. But as the hops so introduced into the beer are not subjected to any process which can destroy the fermentative and other germs, it is not difficult to see what serious mischief may arise unless the greatest care is taken in their selection.

The hops used for "dry hopping" must be most carefully selected. A full but delicate aroma, thorough ripeness without excessive colour, and an absolute freedom from every trace of mildew or other disease, are essentially requisite.

In my opinion the only hops really suitable for "dry hopping" are the finer qualities of Goldings and Worcesters, at any rate for the highest classes of pale ales for home consumption, some brewers use the finest qualities of foreign hops, but I do not like the flavour they give to the beer when used in that way. An exception should, however, be made in the case of export ales, in which "dry hopping" with the finest Spalt hops is sometimes advisable.

If the beers are to be allowed to fine naturally the hops used in dry hopping may be broken up to a considerable extent. But if finings are to be used, samples should be selected in which there are very few broken hops, and they should be so carefully handled as to break as few of the strobules as possible.

The reason for this is that the particles of isinglass agglomerate round the minute morsels of broken hops and are then apt to remain in suspension in the beer and and to appear as "bits" when the beer is drawn. When no isinglass is used this accident is not liable to occur.

New hops are alone suitable for "dry hopping" except at the very beginning of the season. When the hops are first picked they often contain such a large proportion of essential oil, as to interfere with the fining of ales required for immediate consumption, and in this case the brewer may use the hops of the previous season for a few weeks, but the sooner he dry hops with the new crop, the sooner his ales will acquire the fine aroma which these alone are capable of imparting.

The Dublin brewers dry hop some of their finest stouts, especially those intended for export. For this class of beer strength in the hop is of more importance than delicacy, and I am not prepared to say that those are wrong, who use a coarser and stronger hop than I have recommended for ales. Some of the finest qualities of foreign hop may I think be used with advantage in dry hopping export stouts.

The quality of hop which it is most advisable to use in the copper, varies greatly according to the quality of the malt liquor it is intended to produce.

For the finest class of pale ales delicacy combined with strength are the essential characteristics required, the

hops must also be well ripened, and at the same time free from any excess of colour.

When the new hops come first into the market, a small quantity should be at once used mixed with the yearlings, and the proportion progressively increased, until early in the following year the yearlings are entirely dispensed with. If this class of ale is intended for immediate draught, foreign hops should I think, be generally avoided; but for stock ales, the use of a certain proportion of fine Bavarians, or others of equal quality, is of great advantage. Ales brewed with these hops maintain a freshness of aroma even after long keeping, when if the finest Kent or Worcester hops only were used, they would be deficient in this respect.

For the finest mild and strong ales, first-class hops must also be used, but for these ales mere colour is not of much importance, and as regards flavour, a somewhat less delicate hop than those used for pale ales is advisable.

If these ales are for stock a considerable proportion of fine foreign hops may be used with advantage. Bavarians and other good and well flavoured continental hops are suitable for these ales, as are also Californians, and perhaps the finest quality of New York State hops, but ordinary Americans, even of a good class, give a coarse and peculiar flavour, which I think objectionable, although I am aware that all brewers do not agree with me on this point.

A somewhat larger proportion of yearlings may be used, and up to a later period in the season, in this class of ale than in pale ales, but "olds" should not be used in any of these first-class ales. The light bitter and amber ales now so largely brewed for the family trade, require a fairly delicate hop of good quality, but as these

ales are not kept in stock for any great length of time, strength is not of so much importance. For this reason I prefer English hops of fairly good quality and flavour, to foreign hops, for these light bitter and amber ales, but I am aware that all brewers do not agree with me on this point, but consider a small proportion of good foreign hops an improvement. If foreign hops are used for the above ales, the proportion should not exceed one-third, with two-thirds of English, and the foreign hop must not be one characterised by excessive rankness.

When I speak of foreign hops I use the term in its ordinary acceptation as including Continental and American varieties. The hops grown in Australia and New Zealand have as yet been only occasional visitors to our shores, but if they can be imported at a moderate price, they will in the case of another hop famine, prove a great assistance to those brewers who require delicate hops in tiding over the period of scarcity. These Australian and New Zealand hops resemble English hops much more nearly than anything I have seen from any other country. They are picked about the end of February, and can be delivered here in time to supplement our own crop in bad hop years, they therefore, I think, well deserve the attention of the brewers of the United Kingdom.

For the common qualities of mild ales and for porter, the brewer must use his own judgment as to the quality of hops he can afford to use. Old hops must often be used for these common beers, but I would impress upon brewers that they are always more suitable for black beers than for any description of ale.

In black beers of all qualities a proportion of old hops certainly does no harm, and in my opinion is positively advantageous. Sound old foreign hops are very useful

in these beers, and yearling foreign hops of all descriptions may be used with advantage. Even the coarsest American hops, provided they are sound, well-cured, and of good strength, make good yearling hops for stouts and porter, and of course, also, all classes of Continental hops; but poor thin hops, wherever grown, are nearly useless for any purpose after the second year.

To put the matter very shortly I may say that while it is necessary to use such an admixture of new hops and yearlings for the finest class of ales as will maintain as nearly as possible a uniform amount of the more volatile and perishable portions of the products of the hop, this is by no means so important with the commoner running ales, where soundness, good body, and the absence of unpleasant flavours are sufficient to meet the requirements of the customers. In this case yearlings, with a proportion of good sound old hops, and perhaps a few strong new ones as the season advances, will accomplish all that is desired. This remark applies still more strongly to the lower class of black beers, especially if brewed for immediate consumption. For fine qualities of stock stout, on the other hand, a good proportion of strong new hops is requisite, both to aid in the development of the required flavour, and to ensure the beer keeping sound for the requsite period.

CHAPTER XVII.

NON-ESSENTIAL MATERIALS AND CLEANSING SUBSTANCES.

I HAVE hitherto considered the materials essential to the production of beer, namely water, hops, malt, and the various sugars used as partial substitutes for the latter. It now remains to deal with those substances which, though not absolutely requisite in brewing, are occasionally necessary either to meet special trade requirements, or to correct the evils arising from impurities in the essential materials.

Under this head we have isinglass and its various preparations, used to promote rapid fining; caramelised or burnt sugar, used to increase the colour of beers, The various bitters and astringents which are occasionally used to supplement the hops when the crop of the latter fails. And lastly, antiseptics and cleansing materials, such as sulphurous acid and its compounds, salycilic acid; and substances used to purify vessels and utensils, such as strong acids and alkalies, lime, and chloride of lime.

I have already treated of those substances which are necessary to purify waters contaminated with organic matters, and also of those which are required to modify

the composition of waters which are not naturally adapted for brewing. None of these are in themselves brewing materials, they are used either to remove noxious impurities, or to impart the qualities already possessed by natural brewing waters; in which latter case they form part and parcel of the necessary composition of the brewing water.

Well-brewed beers, produced from good materials, nearly always become bright of themselves, after remaining undisturbed for a shorter or longer period, but many customers expect their beer to fall bright in three or four hours after they have received it from the brewer; and, on the other hand, there are many breweries producing fairly good beers, which, owing either to impurities in their water, or some imperfection in their process and materials, lack natural brilliancy even after standing for a considerable time. To meet difficulties arising from either of the above sources, finings are largely used. In the manufacture of wines and some other fermented drinks, various substances, such as egg-albumen and skimmed milk, as well as gelatine, are employed for finings, but the brewer confines himself entirely to the use of the latter, and indeed, as far as possible, to that variety of it derived from the swimming bladder of the sturgeon known as isinglass.

Isinglass is imported from Russia and the countries adjacent, from Brazil and the East Indies, from North America, where it is obtained from the American sturgeon caught in the great lakes, and in small quantities from some other localities. It varies very much in quality and colour, and is also sometimes derived from the swimming bladder of other fish besides sturgeon, as well as from their stomachs and intestines. The qualities from

the latter sources are very inferior, and quite unsuited to the manufacture of brewers' finings. The skins of soles and other flat fish have been also used by some continental brewers with success, but undoubtedly the qualities most suitable for the manufacture of finings are those composed simply of the cleaned and dried swimming bladders of the Russian and American sturgeon.

It should further be clearly understood that any bleaching process, except that naturally derived from solution in sulphurous acid, seriously injures all qualities of isinglass when applied to them. As in so many other substances, paleness of colour is attractive to the eye, and also, when obtained naturally, indicates to a certain extent superior quality. The dealers, therefore, are under great temptations to bleach the inferior kinds of isinglass so as to make them resemble the very high-priced brands, which are naturally free from colour. To the brewer, colour is of absolutely no importance, as long as the sample is perfectly sound, and free from all unpleasant smell and flavour, and is also fairly soluble in very dilute acid solutions. An isinglass with a deep yellow tinge is of equal value with the very whitest quality, provided it contains an equal amount of soluble gelatine.

Until lately, it was the universal custom for the brewer to prepare his own finings from isinglass as imported; this he usually did by steeping it in sour beer for some weeks, till a perfect solution was effected.

I need scarcely dwell on the evils arising from the introduction of acid ferments by the use of finings so made; but, on the other hand, when the brewer purchased the isinglass as imported, it was not difficult for him to discriminate between the various qualities, whereas he is liable to be grossly deceived when he relies on the

ingenious mixtures now so largely advertised as prepared finings.

Some makers prepare and offer to the brewer an article which leaves nothing to be desired, by dissolving really fine isinglass in tartaric or sulphurous acids. Indeed I know several makers who prepare an article, which is everything that can be wished; but I feel sure that the larger brewers, at any rate, would find it greatly to their advantage to revert to the old system of purchasing the isinglass as imported. They can at the same time obviate the evils arising from the use of sour beer by dissolving it in dilute sulphurous and tartaric acids.

The distilled acetic acid of commerce being derived originally from the destructive distillation of wood, is always absolutely free from fermentative germs, and can therefore be safely used in the preparation of finings; it has also the advantage of being very cheap, but it is apt to impart a coarse flavour. Sulphurous acid is cheap and a good preservative, but an excessive quantity of it is objectionable in some cases. Tartaric acid is somewhat expensive, and when finings are cut with it alone they are apt to become very soon mouldy. Taking all things into consideration, I think that finings made with a mixture of sulphurous and tartaric acids answer best, for the sulphurous acid prevents the growth of mould, and the partial use of tartaric acid obviates the necessity for the presence of an excessive amount of sulphurous acid.

These white finings as they are called, when cut with any of the above acids, should be exclusively used for all first-class ales, and specially for those which may have to be kept for a considerable time after they are fined. For common running ales, the old sour beer or brown finings may be employed with advantage, and

when old hard ales have to be blended off in the running ales, it is obviously useless to go to the expense of using white finings. It is a curious fact that the brown finings are considered by almost all brewers, and by all publicans, to be stronger, that is more effective, than white finings, and they are consequently preferred by the retail trade. Whatever acid is used, the process must not be hurried, but the acid must be left in contact with the isinglass for an ample time, extending to a period of frequently some weeks, and in all cases till a perfect solution is effected. A sufficient amount of acid must also be used, and I cannot recommend those preparations of isinglass which are advertised as free from acid.

Good finings consist essentially of isinglass dissolved in an acid solution, not of a mere neutral jelly, such as too many makers of finings manufacture by mechanical processes. These neutral finings appear to be very thick and strong, for a small quantity of isinglass existing as a neutral jelly, makes a much greater show, than a much larger quantity when properly dissolved in an acid solution. The neutral jelly however when tried will be found to have comparatively little fining power.

The following is an excellent receipt for making white finings.

The ingredients are :

7 lbs. of isinglass, Penang leaf preferred,
1 lb. of tartaric acid,
1 gal. of sulphurous acid, of about 5 per cent. strength

The apparatus required consists of three or four hogsheads, with one head removed from each, and provided with close fitting covers. Also some form of sieve to pass the finings through when the isinglass is sufficiently cut. The best forms of sieve are those in which

a brush is made to revolve mechanically over the sieve so as to force the finings through.

The process is as follows :—

Place the isinglass in one of the hogsheads, cover it with water, and add the tartaric and sulphurous acids, previously dissolving the former in a little warm water.

Keep the mixture covered down and well stirred from time to time, adding more water as the isinglass swells, so as to keep the latter covered with liquid. When the isinglass is thoroughly softened pass the whole through the sieve, and dilute so as to make one hogshead of finings from the above quantity of ingredients. A coarse and fine sieve may be used, and the process considerably accelerated by passing the finings first through the coarse sieve and then, in the course of two or three days, finishing their manufacture by passing them through the fine sieve.

Caramel, also commonly known as burnt sugar or colouring, constitutes one of the best materials for increasing the colour of ales, and a proportion of it may be used with advantage in black beers, especially when a brown head is required. For ales it is, I think, a better colouring than black malt, as it gives both a better colour and a pleasanter flavour than the latter, and if properly prepared it can be added to the finished beer, which is often a great convenience.

Caramel is easily prepared from any sugar, by carefully and slowly heating it in a cast-iron pan to about 400° F and maintaining that temperature for a short time. It is then allowed to cool to about 230°, and water is added, very slowly and cautiously at first, to prevent boiling over. Enough water must be added to convert it into a syrup, which can then be used as required.

Care must be taken that the temperature does not at any time exceed 420°, as immediately above that point the sugar gives off torrents of inflammable vapours, and is rapidly and entirely carbonised, so that there is not only the certainity of destroying it, but also serious risk of its bursting into flames.

For black beers intended for immediate consumption, a cheap caramel may be made by heating some of the lower qualities of cane sugar; but for ales, sugars of good quality must be used, and if the ales are required to keep for any length of time, the sugar should have been previously refined.

No beet sugar should be employed. A thoroughly converted glucose has been successfully caramalised, but is not generally so economical a material as cane sugar. If glucose is used, it should be a quality containing very little dextrine.

In making caramel great care must be taken in the heating, for if the sugar is over-heated, or the heating is continued for too long a time, a more or less insoluble modification is produced. The difficulty is to heat the sugar enough to obtain the fullest amount of colour, without producing more or less of the insoluble modifications. There are several varieties of these caramels produced by overheating; some of them are quite insoluble, and remain as a brown deposit when the caramel syrup is drawn off from the pan, they are therefore absolutely lost, and useless to the brewer, but are not actively detrimental.

There is, however, another modification which is very troublesome and injurious. This latter caramel dissolves in the strong syrup, and gives great apparent depth of colour, but when some of the syrup is added to an ale, a

cloudiness quickly makes its appearance, which for the time entirely destroys the brilliancy of the beer, and is by no means easily got rid of. The cloud produced by this caramel generally deposits after a time, but of course leaves the beer paler by several shades than it was intended to be.

For the brewer who makes his own caramel, the best rule is always to under heat it. A partially made caramel, if it has been judiciously prepared by gradual heating, with constant stirring, will not cause any cloud in the beer, and as it yields the extract value of the sugar from which it was made, there is no loss to the brewer, even if he has to use double the quantity, as compared with the stronger caramels produced by the manufacturers of that article.

It seems to me very extraordinary that so few brewers put up the pan with suitable stirrers, which is the whole plant required for making caramel. The expense of the apparatus is comparatively small, and the profit is so large that the brewer can recover the whole cost of the plant in a few months. Those brewers who make and use caramel largely, find it so profitable that they jealously guard the secret, lest their trade rivals should adopt the manufacture, and hence perhaps the reason that so little is known of it in the trade.

There are several manufacturers of caramel for sale, who offer the brewer a first-rate article, and I may here mention the caramel crystals, and powder, manufactured by Lichtenstein & Co., which is a very concentrated form of first-rate quality, and perfectly reliable as far as my experience goes. The only draw-back to the use of these first-class caramels is their somewhat high price, so that it does not pay the brewer

to use them, except occasionally and in small quantities. In fact, owing to the peculiar properties of this material, the brewer can always make it far cheaper than he can buy it. On the other hand a great deal of the caramel commonly sold clouds the beer, and has other objectionable properties. A short time ago I made a careful series of experiments, on the manufacture of caramel on a considerable scale, so that I can speak confidently on the practical aspects of this subject.

Bitters other than hops, commonly known as "hop substitutes," are a class of brewing material which, while deprecating the unnecessary use of, I am not prepared to absolutely condemn, provided always that only such substances are used as are at least as wholesome as hops themselves. Of course the use of any injurious bitter is as wicked as it is utterly illegal, and any one guilty of such an abominable practice deserves to be visited with the severest penalties, but as long as only wholesome bitters are used the public are in no ways defrauded. It is a mere matter of taste, and if they do not like the flavour of the beer, they will quickly compel the brewer, in these days of universal competition, to revert to the use of hops only, or if he persists in brewing beer that the public taste objects to, the ruin of his trade will be the sufficient and appropriate penalty.

Hops, from a dietetic point of view, are a wholesome tonic bitter, but with decidedly narcotic properties; quassia is likewise a wholesome tonic bitter, with slight narcotic properties. Beer, therefore, in which the bitter is partially derived from quassia is quite as wholesome as if hops alone had been used in brewing it. Whether the quassia imparts as pleasant a flavour, is a matter for the consumer to decide. If he likes the flavour of quassia as

well as that of hops he is not defrauded in any way when he buys beer bittered with quassia, it is just as wholesome, nutritious, and tonic, as the beer bittered with hops. The same quantity of the quassia beer will not make him quite so sleepy as the hop beer, but that can scarcely be considered a disadvantage. If, on the other hand, the consumer does not like the flavour imparted by quassia, so well as that imparted by hops, he can purchase his beer from a brewer who uses hops only, and he has thus the power in his own hands of compelling the brewer to use hops and not quassia, if he prefers the former.

This question of the substitution of other bitters for hops is often argued as if it was analogous to the admixture of chicory with coffee, but the resemblance is only superficial, for hops and other wholesome tonic bitters are of about the same average dietetic value, whereas chicory has none of the special and valuable properties of coffee, and its unacknowledged admixture with coffee is a distinct and palpable fraud.

The following is a list of the principal wholesome bitters which may be honestly substituted for a portion of the hops used in the copper. There is no known substance which can be substituted for hops in "dry hopping."

Quassia,	1 lb.	equal in bittering	power to	16	lbs. hops.
Calyso	,,	,,	,,	12	,,
Chiretta	,,	,,	,,	10	,,
Gentian	,,	,,	,,	7	,,
Camomile flowers	,,	,,	,,	5	,,

Quassia, as I have already stated, is tonic and slightly narcotic.

Calyso is a very wholesome bitter, non-narcotic and with a slight stimulating action on the liver. Beer brewed with a proportion of Calyso is more wholesome to most people than that in which hops only have been used.

Chiretta, a very wholesome liver tonic, perfectly non-narcotic.

Gentian, a wholesome tonic bitter.

Camomile flowers are a wholesome tonic, with slightly aperient properties.

As none of the above bitter substances contain any appreciable amount of tannin, this substance must also be added at the rate of one pound of good soluble tannic acid, for every 100 pounds of hops substituted by the other bitters.

Notwithstanding the wholesome character of the above substances, I cannot advise brewers to use them when hops are at a moderate price. The public undoubtedly prefer a beer bittered with good hops only, and therefore brewers who confine themselves to the use of hops, are pretty sure to compete successfully with those who use a proportion of other bitters. When, however, hops rise to an extravagant price, a few good hops used with a proportion of the other bitters, will enable a brewer to produce a beer which the public will prefer both to that brewed with very inferior hops, and also to beers brewed with good hops only, but reduced in gravity to such a point as will allow of a fair profit.

As a general rule, not more than one-third of the hops should be substituted by other bitters, and certainly one-half the usual quantity of hops, and other bitters substituted for the other half, is the extreme proportion in which it is safe to use the latter.

There is one aspect of this question which brewers should always bear in mind, and that is, that none of the other wholesome bitters have anything like the same antiseptic power as hops, and consequently that a beer brewed with the latter will, if other things are equal, keep better than a beer in which other bitters have been substituted for a portion of the hops. Of the substances I have enumerated, calyso comes nearest to hops in its antiseptic properties.

The so-called hop substitutes and hop supplements, are all preparations or mixtures of one or more of the above bitter substances.

I now come to the consideration of the antiseptics and cleansing materials, which constitute a class by themselves. They are scarcely brewing materials, although some of them are added to the beer itself in order to preserve it from the attacks of injurious ferments. On the other hand, many of these substances are used exclusively to wash and purify the vessels, pipes and utensils, in order to maintain that perfect cleanliness which is essential to success in brewing operations.

This class includes in its two divisions,—firstly, sulphurous acid and its compounds, and salicylic acid, which are all used both for washing and cleansing the brewing vessels, etc., and are also added to the beer itself in order to destroy or arrest the action of injurious ferments. And secondly, those substances used for the former purpose only: such as potash, soda, lime, chloride of lime, hydrochloric acid, etc.

Sulphurous acid has long been known as the most available agent for checking vinous and other fermentations. In making sweet cider, it has been used from very early times, and also to control the fermentation of

some varieties of wine. Brewers, on the other hand, have been for many years well aware of its value in preserving their casks and cleansing hogsheads from mould and acidity.

Sulphurous acid is a combination of two atoms of oxygen with one of sulphur, and is most economically produced by burning sulphur in the air.

In the old and well-known process of matching casks, matches were prepared by dipping strips of coarse paper in melted sulphur; these were ignited and introduced into the cask, which was then bunged down. Under these circumstances, the sulphur combines with the oxygen of the air, and an atmosphere containing sulphurous acid is produced. This acid is freely soluble in, and has a strong affinity for water, and consequently saturates the moisture in the pores of the wood, thus destroying all organisms at any rate near the surface, and preserving the cask for a period of some months.

To check fermentation, the vinous liquid, whether cider, wine, or beer, was formerly racked into the casks after matching, and was thus brought in contact with air more or less saturated with sulphurous acid, which latter the liquid absorbed.

Sulphurous acid combines with various bases forming sulphites, and these combinations have of late years been brought under the notice of the brewer in a vast variety of forms. They may be classed generally under two heads—the neutral and acid sulphites. The former being a combination of one atom of the acid with one of the base, and the latter of two of the acid with one of the base.

The sulphites at present used in brewing are the mono and bisulphites of soda, potash, lime and magnesia,

and occasionally the sulphite of ammonia. Sulphurous acid itself is only now used for dissolving isinglass, and for cleansing purposes.

The most extensively used of all the sulphites is the solution of bisulphite of lime, so well known to every brewer. It is made of several strengths, the specific gravity of the solutions usually offered to brewers varying from about 1050° to 1070°. For cleansing purposes the value of this solution depends on the amount of sulphurous acid which it contains, which, in proportion to the lime, is nearly always in excess of what would be required in order to form a true bisulphite. When the bisulphite of lime is added to the beer this excess of sulphurous acid is objectionable, and should be kept within the narrowest possible limits, for there can be no doubt that the liability to produce "stench" in the beer to which it is added, varies in the case of all sulphites, in the direct ratio in which the sulphurous acid present exceeds that required to form a monosulphite.

In other words, the monosulphites are less liable to produce "stench" than bisulphites, and bisulphites which contain just two equivalents of acid to one of base, are less liable to produce "stench" than those in which the acid is present in a larger proportion.

Both bisulphites and monosulphites which are to be added to beer, must be free from hyposulphites, which are great promoters of "stench," and as free as possible from iron, of which metal however even the best samples generally contain a trace.

Monosulphite of lime is now largely employed, and is an excellent preservative when pure. It is, however, troublesome to use owing to its slight solubility, in consequence of which it has to be weighed or measured,

and added to the beer as a dry powder. As generally sold it too often contains a considerable amount of iron, and I have not found the samples submitted to me, usually so pure as the bisulphites of lime which I have examined.

There is a special preparation of sulphite of lime, sold under the name of hydrosulphite, only a portion of the lime in which is saturated with sulphurous acid. It is, of course, weight for weight, a weaker antiseptic than the ordinary monosulphite of lime, over which it appears to me to possess no advantages. The addition of hydrate of lime to beer, unless the latter contains an excess of acid, so far from being advantageous is distinctly objectionable.

Both the monosulphite and bisulphite of magnesia are excellent antiseptics, and appear to be rather more powerful than the corresponding lime salts, and perhaps also less liable to produce "stench." As regards solubility there is very little difference between the magnesia and lime salts. They are liable to contain the same impurities, but the commercial samples are generally pretty pure. The magnesia sulphites are more expensive than the lime sulphites, but many brewers consider them so much superior as to be well worth the extra cost.

The monosulphite and the bisulphite of soda are very valuable antiseptics and largely used, the latter constituting the well-known Beane's material, the patent for which has lately expired. When using these sulphites care should be taken that there is a sufficient amount of the chloride of either calcium or magnesium present in the brewing water, to ultimately decompose the soda salts and convert them into chloride of sodium, and the corresponding lime or magnesia sulphites or sulphates.

I have before pointed out the necessity of always having an excess of the above chlorides present in the brewing water; whether they are present naturally or are artificially added is a matter of no importance. It is to the neglect of this precaution that I attribute the irregularity in the action of the soda sulphites in different breweries.

The sulphite of ammonia is occasionally used, it is a very expensive salt, but it is an excellent yeast stimulant as well as an antiseptic, and combined with phosphate of potash forms a most valuable yeast food and purifier.

The sulphites of potash are also valuable antiseptics, and the well-known firm of Boake & Co., has lately introduced an excellent and very powerful variety of the above, under the name of kalium metasulphite.

Salicylic acid is a comparatively new antiseptic, and when first introduced it excited some enthusiasm amongst our principal brewers. In my first edition, published just after its introduction to the brewers of the United Kingdom, I thus allude to salicylic acid :—

"This new antiseptic claims the attention of every brewer, for while fully, if not more effective than sulphurous acid and its compounds, as a preservative and antiseptic, it has comparatively little taste, and, indeed, when added only in the necessary proportions required to preserve the beer, cannot be detected in the latter by the flavour. In this respect it forms a pleasant contrast to bisulphite, the nauseous flavour of which is unfortunately so prominent in the ales even of many of our best brewers during the summer months.

About half an ounce to an ounce of salicylic acid per barrel is usually an ample proportion to secure beers from deterioration and acidity during the hottest

weather. This it accomplishes by means of its power of destroying the vitality of the false ferments. When not used in excessive proportions it has but little effect on the vital powers of the yeast-cells. The beers to which it is added consequently retain their briskness and condition, while their keeping qualities are enormously enhanced.

One of a series of experiments I have been conducting on the powers and properties of salicylic acid very aptly illustrates its action. I prepared a quantity of boiled but unhopped wort, and placed an equal portion in two flasks of about the same capacity: into one of these I introduced one grain of the acid, and placed both of them, with their mouths open, on the same shelf.

On examining their contents after twenty-four days, the one containing no salicylic acid was very foul in smell, and the microscope showed it to be full of vibrios and other butyric and putrid ferments, but no yeast-cells; while that containing the acid was perfectly sweet and sound, free from false ferments, and contained only a few torule cells."

An antiseptic free from unpleasantly active medicinal properties, and which gave neither taste nor smell to the beer, and yet preserved it, appeared to be exactly what the brewers required, but unfortunately one or two years experience has demonstrated the fact that salicylic acid when added to beer has one fatal defect.

Although itself practically tasteless, when first added, salicylic acid frequently, after the lapse of a few months, causes the beer to acquire a most peculiar and objectionable flavour, which nothing afterwards appears either to alter or remove. It is difficult to describe this flavour, but when once tasted it will never be forgotten, and a

man must be very thirsty who will drink a second glass of a beer that has acquired it. It is very remarkable that the flavour of some beers appears to be very little affected by the presence of salicylic acid, even after long keeping, whereas other beers even brewed in the same locality, and from the same qualities of material acquire the objectionable flavour a few months after the salicylic acid is added. There is, however, always the risk of the flavour of the beer being spoilt, and this is the reason that such a comparatively small amouut of salicylic acid is used.

The outcry against the unwholesomeness of salicylic acid, raised in France, is simply absurd, and appears to have arisen from no more rational cause than national jealousy. Kolbe, the discoverer and patentee of the cheap process for producing salicylic acid, is a German, and that appears to be a sufficient reason in the eyes of many Frenchmen for concluding that salicylic acid is deleterious. Experience, however, has proved distinctly that this antiseptic is one of the safest and most wholesome that can be introduced into the human system; while its efficacy as a remedy in rheumatic and some analogous painful affections, ought to secure for Kolbe the warmest gratitude of mankind.

There is one peculiarity of salicylic acid, which must always be borne in mind, and that is that it only acts as an antiseptic when in the free state, or perhaps it would be more correct to say, when the solution containing it has an acid reaction. As beer always has an acid reaction in its natural state, a solution of a salt of salicylic acid added to beer, is as effective an antiseptic as the equivalent amount of salicylic acid itself. Burbidge took out a patent based on this latter fact, which

I discovered when investigating the properties of salicylic acid for the well-known firm of which he is the senior partner. Kolbe, misled by the fact which he had discovered, that the salts of salicylic acid were not themselves antiseptics, combated my views at first, but experience has proved that I was right.

As far as the brewer is concerned, one of the chief uses of salicylic acid is its addition to quick draught beers, brewed from inferior materials, in order to postpone their deterioration for a few weeks. There is no risk in this, as it always takes several months before the objectionable flavour develops. Then again, this antiseptic is very useful for purifying the yeast, for which purpose it may be used as a dressing in the fermenting tun, in the proportion of about one ounce to four barrels of beer. It not unfrequently happens that when sulphites are used constantly in the earlier stages of brewing, certain organisms survive, and become callous to the action of those antiseptics. In such cases they will often succumb to a dressing of salicylic acid in the above proportion.

As brewers frequently possess valuable animals liable to be attacked with the foot-and-mouth disease, I may mention here that salicylic acid is a rapid and certain cure for this dreaded plague.

I have already alluded to the value of salicylic acid when used on the malting floors to prevent mould.

The above are the only antiseptics which can be added safely to beer, but both these and many other substances can be used with advantage for purifying the vessels, pipes, and utensils of a brewery.

Although a wash with bisulphite of lime is now the favourite method with most brewers for destroying the

disease ferments in the brewing vessels, sulphurous acid, obtained by burning sulphur in the vessel itself, or in the room in which the vessel stands, is often both more effective and cheaper than the use of the bisulphite of lime solution. It is, however, somewhat more troublesome, and requires perhaps greater care in its application. The simplest and best method of applying sulphurous acid produced by burning sulphur is as follows: After thoroughly scalding and cleansing the vessel, mop it over with cold water, so as to leave its sides thoroughly wet; a pan with a few red hot coals in it is then placed in the vessel, and some flowers of sulphur thrown on the coals; the vessel is then at once closely covered down and allowed to stand for twelve hours or more.

Some brewers sulphur the whole fermenting-room at one time. In this case the sulphur is thrown into a pan of red hot coals placed in the room. Every aperture is carefully closed, and strips of paper pasted over the joints of the doors, windows, and any other chinks and apertures, so as to prevent all ingress or egress. The fermenting vessels must of course be all empty and well washed, and mopped out, so as to leave their sides thoroughly wet, as in the previous case. This is a very efficient method of destroying false ferments, but involves the interruption of the brewing operations, so as to have the whole of the fermenting vessels empty at one time.

In cases where the brewery utensils have become so seriously contaminated with false ferments that these are not completely destroyed by sulphurous acid, chloride of lime solution, made in the proportion of a pound or more to the gallon of water, and well mopped over every portion of the vessel, has a very beneficial effect. It should be allowed to remain on for twenty-four hours,

then thoroughly washed off with an abundance of hot water, and sulphurous acid or bisulphite of lime subsequently applied to the vessel in such quantities as to make it smell strongly of sulphurous acid. By this means the whole of the chlorine is converted into hydrochloric acid, which can then be easily removed by washing with water.

Moderately strong solutions of the alkalies, either in their caustic state or as carbonates, are valuable for cleansing pipes and those other portions of the plant constructed of metal.

These alkalies in their caustic state are the most effective and the safest substances for cleansing vessels made of slate and stone, such as the Yorkshire stone squares, and ordinary slate fermenting tuns and racking backs. The surface of the stone and slate are liable to be injured by the action of the sulphurous and other acids, and it is therefore necessary to have recourse to the alkalies.

Caustic potash is more effective, but also more expensive than caustic soda, but either of them may be used by applying its solution to the surface of the slate or stone by means of a mop made of cotton rags, and supplementing the action of the alkali by brushing and scouring.

Strong mineral acids are valuable in experienced hands for cleansing copper pipes and utensils, but as their action is powerfully corrosive, it is not safe to allow the ordinary workmen in a brewery to use them at their discretion.

Having now concluded my remarks on the materials used in the brewery, both for the production of the beer itself, and also for cleansing purposes, I shall in the next chapter enter on the third section of my subject, viz.: "The Process of Brewing."

CHAPTER XVIII. SECTION III.

PROCESS OF BREWING—MASHING.

IN the previous chapters, I have considered the best methods of constructing the brewery and its utensils, and also the characteristics of the various materials used in the manufacture of malt liquors. I have now to enter upon the details of the process of brewing.

In some respects this must be looked upon as the most important of all the sections into which I have divided the subject for while an inexperienced or ignorant brewer will produce very imperfect results, even with the best materials and apparatus, the really scientific and practical brewer, by availing himself of all those aids which science and experience have placed within his reach, will produce an article of tolerably good and uniform quality, even under excessively adverse circumstances.

Taking the brewing operations in the order in which they naturally follow one another, we have first to consider the raising of the water from its natural source, and its preparation for the mash.

Where the brewery is in constant operation, and, as should be universally the case, a special set of pumps is provided for pumping the cold brewing water, the necessary precautions are of the simplest character.

The water should, as far as possible, be pumped directly to the hot liquor back or copper, and, if the pumps have been standing for some hours, it is as well to reject that first rising through them, especially where the water is so soft as to be liable to dissolve metallic substances.

When brewing has been suspended, or the well from any other cause has not been pumped for a considerable period, it should be completely emptied, the water being pumped to waste, so as to obtain that rising fresh from the springs. The cold water tanks should be frequently emptied, and scrubbed out at least once a week, and, in fact, every precaution should be taken as far as practicable, to supply the hot liquor back with water, fresh from the filtering and purifying action of the earth.

The necessity for this will be at once seen if it is considered how rapidly organisms are generated, even in the purest waters, when exposed to the air, although that exposure is mitigated as far as practicable, by covering in the reservoirs.

If the water is free from organic impurities, and also from iron, and all other deleterious matters, and if it also contains these sulphates, chlorides and other useful mineral ingredients, in the proportions suitable for the class of malt liquor which is to be brewed, it is only then necessary to heat the water to the mashing temperature. But, as nearly all waters are liable to contain some organisms, and also traces of dead organic matter, it is generally advisable to heat the bulk of the water to the

boiling point, and then to cool it down to the mashing temperature, by running freshly pumped cold water into it.

If the water contains any appreciable amount of organic impurities, these should be removed by filtration through animal charcoal, as described in Chapter XIV. After filtration as much of the water as possible should be boiled and either allowed to cool down naturally to the mashing temperature, or else cooled at once with cold filtered water.

There is another process of purifying water containing organic matters besides filtering which is sometimes adopted with success. It consists in adding bleaching powder, commonly known as chloride of lime, to the water which is then boiled and allowed to cool naturally. When water is treated in this way it is always advisable before using it for brewing, to add a sufficient quantity of bisulphite of lime, to remove the smell of the chloride of lime completely.

This process requires careful manipulation, but if carried out successfully, the organic matter is oxidised by the chloride of lime and the traces of the latter still remaining in solution, when the oxidation is completed, are converted into chloride of calcium by the action of the bisulphite of lime.

This method would no doubt be more widely adopted, were it not for the objection brewers have, to adding such a strong smelling substance to the brewing water, and the manifest risk of undecomposed chloride of lime finding its way into the mash through carelessness.

For these reasons most brewers prefer the safe and sure plan of filtration.

If iron is present in the water it can nearly always

be precipitated by boiling. The water must be boiled briskly for twenty or thirty minutes, some hours before it is required for mashing. After the ebullition the water must be allowed to remain at rest, until the precipitated iron has subsided, and only the clear water must be used for brewing. The water may be allowed to cool naturally, or when clear it may be run into a second back, in which it is cooled either by means of a coil, or by running in cold water free from iron, if such can be procured. The best apparatus for effecting these objects has been fully described in Chapter V., and I need only add that care must be taken that the cock for running the water to the mashing machine or tun, is inserted at a sufficient height above the bottom of the hot liquor back, to allow the precipitated and deposited iron to remain behind.

Iron may also be removed from water by means of char filtration previous to boiling, but if that metal is present to any considerable extent, it is apt after a time to choke the pores of the char.

I have already treated so fully in Chapter XIV., of the salts which the water ought to contain, either naturally or artificially added, for each class of malt liquor, that I need not here revert to this portion of my subject. If difficultly soluble substances, such as sulphate of lime, have to be added to the water, they should be in very fine powder; they must also be thoroughly mixed with the water, and kept suspended in it by rousing or ebullition for fifteen or twenty minutes. Soluble substances and strong solutions should be mixed with the water by a few minutes rousing or boiling.

In badly arranged breweries it is often difficult to mix the salts thoroughly with the water, or there may be an

objection to doing so, owing to the water from the one hot water back being used for feeding the boilers or other purposes as well as for brewing. In such cases the various salts may be added, if in dry powder, to the grist; or about two-thirds to the grist, and one-third by sprinkling over the surface of the goods when about half the wort is run off. Solutions may be run into the mash tun with the mash, if outside machines are used, or added to the water in the tun, if rakes only are employed; about one-third being reserved and added later on as the sparging proceeds.

In the preparation of the malt for the mash tun, it is first passed through a coarse screen in order to remove stones and other large foreign bodies, it is next passed over one or more fine screens, the finest of which remove rootlets and dust from it, and finally on its way to the mill magnets, already described in Chapter VI., remove any nails or other pieces of iron.

As regards the grinding itself the rule is always to grind as fine as is compatible with the production of a sufficiently light and buoyant mash. Every corn should at least be cracked, otherwise there will inevitably be a loss of extract, and as the corns even in the finest sample of malt vary greatly in size, there is an immense advantage in the use of the four-roller mill, one pair of rolls being set so as to grind the large corns just sufficiently, while the other pair are set up as close as possible, so as to thoroughly crush the small corns separated by the screen. The same object may be attained with one pair of rolls, but at the expense of a good deal of trouble and loss of time, by grinding the small corns separated by the screen, after the bulk of the malt is ground, and after first setting the rolls up close together.

When a proportion of non-germinated corn is to be mixed with the grist, the best plan is to pass it through the rolls with the ordinary malt, and if a four-roller mill is used it is generally advisable to pass it through the pair set close up for the small corns. If the non-germinated corn has been already partially ground during its preparation, as is the case with my Patent Pale Malt, it must not be passed over any screen, but run direct to the rolls from a small hopper provided for the purpose.

Fine grinding will give the largest and best extract, provided it is not carried so far as to produce a dead mash ; but if the malt is ground so fine as to destroy the buoyancy of the mash more extract may easily be lost owing to the defective percolation of the sparge, than is gained by the fine grinding.

There are an immense number of modifications of the mashing process, varying with the machine used and the prepossessions of the brewer. The objects aimed at, however, do not vary so much as the means by which it is sought to attain them. These objects may be very shortly stated to be, the perfect and rapid admixture of the ground malt and water, so as to obtain a mash of a certain definite temperature and with a certain definite proportion between the amounts of malt and water so mixed. It is also now a fact generally recognised, that the lower the temperature of the water the better will be the results, provided the right temperature and the right thickness of mash are obtained. The points, therefore, we have to consider are, what is the best heat for the mash, what are the best relative proportions for the malt and water, and how can these conditions of the mash be obtained, with water at the lowest temperature compatible with them.

Very considerable divergencies of opinion exist among brewers as to the most suitable mashing temperatures, and these divergencies have been greatly aggravated by the practice of judging the temperature of the mash from the tap heat. Now, as this tap heat may be modified to almost any extent by the length of the pipe from the mash tun to the point where the temperature of the wort is taken, and also by the speed at which the wort is run off, it is evident that far greater reliance can be placed on the fairly uniform results arrived at, by taking the temperature of the mash itself, by means of a well-constructed mash tun thermometer plunged into it. The best form of mash tun thermometer, is that with a naked bulb, and a tube sliding over it, to protect it, while it is being thrust into or withdrawn from the mash. The scale is most conveniently placed some two or three feet above the bulb, and the whole instrument should be from three to four feet long.

The heats I am about to give are such as would be registered by the instrument just described, plunged into the mash at a point about equidistant from its centre and circumference, and to a depth of from about half to two-thirds of the total depth of the goods.

As regards the best temperature for the mash, this will vary with the quality of the malt, and also of the beer that it is intended to produce. As a general rule, the more fully a malt is grown, and the lower the temperature at which it has been dried, the larger will be the amount of diastase which it contains, and the higher will be the mashing heat to which it can safely be subjected. Malts, which for any reason are deficient in diastase, will not stand such high heats as those which contain a large amount of that substance.

Then again, if the grist contains a proportion of non-germinated corn, not only must the initial heat be lower, because there is less diastase, but also because there will be a greater rise of temperature in the goods, consequent on the more active hydration which takes place.

Keeping the above data in mind I may say that the heat of the mash taken as above, and about twenty to thirty minutes after it is completed, should for ales never exceed 154° F., or fall below 148°. From 150° to 152° is a range which will give good results with the vast majority of malts, and during the time the mash stands before setting tap, the temperature should be at least maintained, even if it does not rise slightly. If there is any fall in the temperature, it is a certain proof that the mashing plant is defective, and steps should at once be taken to correct the defects.

For black beers a considerably lower range of temperature is considered advisable by many brewers, especially those of London and its neighbourhood. The range of temperature for black beers may be taken at from 144° to 150°, the lowest heats being used by the London porter brewers. These low heats for black beers are quite in accordance with the general rule I have laid down, there being inevitably much less diastase in the mixture of malts used for stout and porter, than in pale malts. In fact, black malt can contain no diastase, brown malt scarcely a trace, and even in amber malts the amount of diastase is frequently very small.

As regards the proportion of the water to the malt in the mash, this must vary to some extent, according to the strength of the beer which it is intended to produce. The limits however which will give good results in our simple mashing plant, are not very wide; about one and

three-quarter barrels per quarter being almost the stiffest, and two and a half barrels per quarter about the thinnest mash which I can advise any brewer to employ.

For strong ales, and with a mashing plant consisting of a Steel's machine, driven so that there is no danger of belts slipping, or other accidents, combined with internal rakes, it may be possible to make a good mash with one and a half barrels per quarter, but that is certainly the extreme limit of stiffness permissable under any circumstances. On the other hand, good results cannot be expected with a mash consisting of more than two and a half, or at the outside two and three-quarter, barrels per quarter, and if the mashing apparatus is in proper order, there can I think seldom be any valid reason for exceeding two and a half barrels.

The above proportions of malt and water apply to good average English malts, weighed up to 336 lbs. per quarter, the natural weights varying from say 38 lbs. up to 42 lbs. per bushel. When light foreign barleys are used, and strong beers have to be brewed from them, without the use of sugar, brewers must exercise their own judgment, but even then I think one and a half barrels per quarter of 336 lbs. will generally be found to be as stiff a mash as can be resorted to with advantage.

Those brewers who use a considerable proportion of sugar, have much more liberty in the matter of the stiffness of the mash, than those who brew from malt alone, and I must here point out the great advantage there is in the use of a proportion of Condensed wort for brewing strong beers. Ordinary sugars do not give a strong beer of the character generally required, and when malt alone is used, excessively stiff mashes have to be resorted to, or else the troublesome and unsatisfactory

system of party gyles has to be adopted. All these difficulties disappear when a proportion of Condensed wort is used. Both party gyles and excessively stiff mashes can then be dispensed with, and the worts being brought up to the required gravity by the addition of Condensed wort, the beers will still retain their all malt character.

Although as I have stated above, mashes ranging from one and three-quarters up to two and a half barrels per quarter of 336 lbs. of average English malt, give good results, I think that mashes of from two up to two and a quarter barrels are to be preferred to all others, when other circumstances do not compel the brewer to use different proportions.

It must be clearly understood that the above remarks only apply to mashes made by means of our simple infusion plant. When the decoction system, or any of its modern modifications is adopted, much thinner mashes are advisable, especially if a large percentage of ungerminated grain is used.

The system of mashing must in every brewery depend to a considerable extent on the form of the mashing plant; but, although there are an immense variety of mashing machines and appliances, the mashing plant in every brewery, and the consequent system that must be adopted, will in all cases be found to be included under one of the three following heads, viz:—A mash tun with rakes and no external machine; an external machine and no rakes in the tun; or, lastly, a combination of these two systems.

Whatever the plant may be every portion of it must be examined and its perfect cleanliness ascertained before the mashing is commenced. Before the malt is

ground the grist case and its slides must be examined and all stale and damp particles of malt carefully removed. Outside machines, if used, must be examined, and if not perfectly clean they must be washed with plenty of boiling water. Lastly, the mash tun and its plates must be examined, their perfect cleanliness ascertained, and the underflow pipes well flushed through with boiling water before the plates are laid down and secured.

The taps should now be all opened, and then, if the mash is to be made with rakes in the tun itself, the water should be set running into the tun at or only slightly below the boiling point. A soon as the water runs clear and at the full temperature from the taps these are closed, and the water shut off as soon as the desired quantity is in the tun. While the water is being run in and for a short time afterwards the covers of the tun should be kept closed, so as to subject every portion to the heat of the steam rising from the water. After about half-an-hour the covers are opened, the rakes set in motion, and the water allowed to cool to the mashing temperature, or if that would occupy too long a time, and pure cold water is obtainable, a sufficient amount of it may be run in to accelerate the cooling. Care should always be taken to have a sufficient amount of water in the tun, and as the heat of the former approaches the mashing temperature, the dip must be corrected by running some to waste if necessary.

The exact amount of water being in the tun, and at the exact temperature required, the cover is closed, and the rakes kept revolving at such a speed that they will traverse the whole circumference of tun once in from 40 to 60 seconds. The slides of the grist case are now

opened wide and the grist run rapidly into the tun. After all the malt is in, the rakes are kept going for about fifteen minutes, so as to insure a perfect admixture of the malt and water, and then stopped. The heat of the mash should now be ascertained, and after it has stood for about fifteen minutes a small quantity of water, at a higher temperature than that already used is run into it through the underflow pipes. The rakes are then run again about thrice round the tun so as to equalize the heat and the mash is completed.

Of course the temperature of the water which is required will vary slightly according to the temperature and quality of the malt, the size of the tun, and other circumstances, but a brewer will not go far wrong if for beers of ordinary gravity he uses two barrels per quarter at from 160° to 162°, and an underflow of one quarter of a barrel per quarter at a temperature of 170° to 175°. His aim should be to obtain a first heat of the goods of 149° to 150°, and a final mash heat of 152° to 153° taken half an hour after the rakes are stopped for the second time.

When external machines are used, some further precautions are necessary, for in this case special means must be adopted for heating the mash tun to somewhat above the mashing temperature, or no good results can be expected. This heating of the tun is important whatever may be the material of which it is constructed, but with cast iron tuns it is absolutely essential, owing to the great weight of metal which comes in contact with the mash, and which if cold, will continue to abstract heat from it, until the heat of the metal and of the mash are equalized. The enormous cooling power of cast iron tuns has not hitherto been generally appreciated

by brewers, and these tuns have been frequently condemned, when the expenditure of a few shillings would have rendered them at least as efficient as the best wooden tuns. As I have already stated in Chapter VII., there is only one method by which cast iron tuns can be effectually heated, viz: by means of steam injected freely into them, but I also apply this method of heating to all tuns whatever may be the material of which they are constructed.

In order to heat the mash tun the steam should be turned on, and also the taps, about an hour before mashing, with the covers carefully closed. As soon as the tun is sufficiently heated the steam is turned off, and some water is run through the machine, the underflow pipes, and the sparger, until the water flows from the taps at its full heat; these are then closed, the plates just covered with the mashing water, and the mash run through the machine into the tun. If there are no rakes in the tun, the temperature of the underflow should not greatly exceed that of the original mashing water, except in small tuns in which the mash can be stirred up by hand. If the mash is not going to be stirred at all in the tun, the underflow should be run in very slowly so as to give it a chance of percolating evenly upwards through the whole of the goods.

When there are rakes in the tun I finish the mash exactly as if it had been made originally with the rakes, running in the underflow at about 175°, and about fifteen minutes after the mash is all in the tun, or as soon after as the water can be raised to the required temperature, and then running the rakes thrice round. I may mention here that during this final application of the rakes it is not necessary to run them at a higher speed than once

round in two minutes, or at half the speed I have recommended in making the original mash with rakes only. Either more than three turns, or a very high speed are both liable to produce heavy goods which will not rise well to the sparge. In large tuns with a double tier of rakes, two turns are generally sufficient and the rakes should be reversed for rather less than a quarter of a turn before finally stopping so as to level the goods.

Provided the tun is thoroughly heated by blowing steam into it, the same temperatures may be used with outside machines as with internal rakes, and will produce the same mash heats.

As regards the necessary variations in the mashing heats under varying conditions, I may say that new malts as a rule require rather lower heats than old malts. When also the grist contains a proportion of ungerminated corn the heats must be lower than when every corn has been well grown up. This latter rule is equally applicable whether the presence of non-germinated, or partially germinated corns, arises from imperfections in the barley, or from the intentional addition of non-germinated grain.

The mash being completed must be kept carefully covered down, and protected as far as possible from everything that would tend to lower its temperature, such as draughts of air striking on the sides, top or bottom of the tun.

There seems to be a general agreement amongst experienced brewers, that two hours is the time the mash ought to stand. This time is generally reckoned from the first stopping of the rakes, until the taps are set.

I believe that this opinion is quite correct and that

two hours standing of the mash is a safe rule to adhere to. This time certainly can be seldom reduced with advantage, and unless there are some special means of keeping up the heat of the goods, it ought not to be exceeded by more than half an hour, or the temperature of the goods will begin to fall to an injurious extent. Besides this danger it is quite possible that organisms whose germs always exist in the brewing materials, may commence to develop in the upper and cooler strata of the mash, if it is allowed to stand for an excessive length of time.

There are various means and appliances which may be adopted for keeping up the temperature of the mash or even for increasing it.

With the ordinary mashing plant this object may be effected by means of the heating vessel and pump already described in Chapter VIII. This vessel, it will be remembered, is placed above the tun, and is furnished with a steam coil and strainer. The wort is pumped into it by means of a small centrifugal pump, the suction main of which is connected with the bottom of the mash tun. The wort, after being heated in this vessel, is returned to the mash through the sparger, and this process goes on continuously, until the brewer has raised the heat of the goods to the point which he desires This is a good system, but requires certain precautions to enable it to be safely carried out. In the first place arrangements must be made to prevent a vacuum being formed below the mash, in the event of the pump taking the wort faster than it can percolate through the goods. An air pipe connected with the suction main of the pump, and extending upwards to above the level of the top of the tun, will prevent any risk of such a vacuum

being formed, and of the consequent collapse and fracture of the plates of the false bottom which is apt to ensure. The other precautions which are necessary are, to maintain perfect cleanliness throughout the mains and pump by passing both hot water and steam through them after and before every brewing, and lastly, to watch most carefully the temperature to which the wort is raised in the heating vessel, and also the temperature to which the goods are raised by this hot wort. It must always be borne in mind when dealing with the heat of a mash, that the diastase in it is greatly weakened by a temperature of 160° F., and that its power is entirely destroyed at a temperature about 10° higher. It is a safe rule therefore never to allow the wort in the heating vessel to rise quite as high as 160° F., unless it is desired to weaken or destroy the diastatic power of a portion of the wort for some special purpose, such as the increase of the dextrine percentage.

There are various forms of mashing apparatus which are specially designed to raise and control the temperature of the mash. For instance, jacketted mash tuns may be used, and the temperature of the mash raised by admitting steam, or water heated by steam, into the jacket. Then again, Tizzard's hollow rakes may be employed, and if they can be constructed on some plan which will insure sufficient strength, these hollow rakes are probably one of the most efficient forms of apparatus for raising the heat of the mash, especially if used in combination with jacketted mash tuns.

If efficient means are provided for heating the mash, the brewer may commence operations with a thinner mash, and at a lower temperature than I have indicated, and may finally raise the heat of the mash to 158° F,

or even higher. In fact he may employ a modified decoction process instead of the simple infusion method.

Besides the above systems of heating the mash, there is the decoction plant, and the various forms of converter which effect the same object. I shall, however, postpone for the present, the description of the methods of working adopted with these forms of apparatus, and will now complete my description of the ordinary English infusion system by a consideration of the heats and precautions which it is necessary to adopt, in order to wash out the wort from the goods in the most efficient manner.

The sparger is now universally employed for this purpose, but owing to some starch always remaining unconverted in the goods, certain precaution are necessary. If water at or near the boiling point is sparged over, goods mashed on the infusion system, soluble starch will inevitably be formed, and as soon as all the diastase has been destroyed in the goods, or washed out of them, soluble starch will make its appearance in the wort as it flows from the tun.

Soluble starch in the wort is the sure precursor of beers that fine with difficulty, and rapidly become unsound, in fact to the presence of this body in the worts must be attributed those special difficulties from which all ale brewers suffered more or less when they abandoned the system of extracting the wort from the goods by repeated mashes, and adopted the modern process of sparging.

When the goods were mashed up again, even a third time, and no sparger was used, there was always some diastase left, provided the temperature was kept well below 170°. This diastase had time to convert any soluble

starch that was formed, during the time the mash was allowed to stand for the worts to become bright. On this system, and with first-class malt, I have frequently seen a perfect second, or even third wort run off at 165° quite free from starch, and brewers, when they first adopted the sparger, thought that an equally high temperature might be employed with impunity with that utensil. Disastrous experiences, however, soon undeceived them, and compelled them to lower their sparging heats, but even now, many brewers have no very clear conception of exactly what heats are safe, or how to determine with certainty when they are approaching the danger point.

The limits of safety vary to a certain extent, according to the quality of the malt, for the more perfect the malt, the more perfect will be the conversion, and the higher will be the sparging temperature that can be applied to it with safety. As there is no particular advantage, however, to be derived from this high temperature, the safer plan is to adopt such heats as will not prove injurious with materials of an average quality.

Following the plan which I have already explained, of taking the heat of the goods themselves, instead of that of the taps, the general rule is that the heat of the goods must always be kept below 160°, or, to go into fuller particulars, and commencing with the goods at a temperature of 152° when the taps are set, such sparge heats should be used as will raise their temperature to from 156° to 158° F. in from two to three hours. The temperature of the goods after that time should be allowed to fall slightly, but never quite as low as the original temperature of 152°, and certainly not below it.

The heats of the sparges required to produce the above

temperatures vary considerably in differently constructed breweries, but I may say generally that I usually commence with a sparge of one-half to three-quarters of a barrel per quarter at a temperature of 170° to 175° F. so as to warm the upper strata of the goods, which have become cold during the two hours' standing after mashing. A second sparge at a temperature of 160° to 165° will generally be found to have raised the goods to the highest temperature permissable, and as soon as that is the case all the subsequent sparges must be run on at temperatures below 160°, except in cases where the goods have had to stand for some time. When the surface of the goods has been cooled by standing, a few barrels of hotter sparge are necessary in order to restore the heat that has been lost.

The above sparge heats are those applicable to tuns provided with tightly fitting covers of some non-conducting material. With more or less open tuns, or exposed metallic covers, the brewer must prove for himself what sparge heats will give him the right temperature in his goods.

With the above temperatures there is but little risk of soluble starch contaminating the worts, but it is always advisable for the brewer to test occasionally for starch, and more especially when he commences to use a new lot of malt, of the quality of which he is not certain.

This testing wort for starch is a most simple process, and is effected by adding a solution of iodine. The ordinary tincture of iodine kept by all druggists answers well enough, although that made by dissolving iodine in a solution of iodide of potassium is perhaps better. The solution of iodine must be added drop by drop, to a teaspoonful or two of wort, taken as it flows from the

taps, and cooled as quickly as possible. The first drops of iodine solution are generally decolourised, and more must be added until a permanent colour is produced. If this permanent colour is deep indigo blue or nearly black, soluble starch is present in large quantities. If a purple colour is produced there is a little soluble starch, together with the dextrine that approaches nearest to it in character. If the colour is a deep orange red, only this erythro-dextrine is present, and no starch. When the iodine colours the wort deep red while there is a good deal of it still to run off, the heat must be lowered or soluble starch will probably soon make its appearance. Of course an excess of the iodine solution will impart its own orange brown colour to the wort, but a little experience will enable the brewer to distinguish it from the red produced by erythro-dextrine.

The cause of frequent mistakes in this method of testing, is the addition of too small a quantity of the iodine solution. This is at first decolourised even if the wort contains starch, and the brewer consequently fails to detect the latter. By continuing to add the iodine solution drop by drop until a permanent colour is produced, all risk of error from this cause is avoided.

I have hitherto spoken only of the sparging heats which produce the best results in brewing ales, I will now point out the heats most suitable for black beers. The usual practice in most porter breweries is to sparge at a high temperature, keeping the sparge throughout at 180° F., or even higher. There can be no doubt but that soluble starch passes through with the worts, when these high temperatures are used, but for black beers this does not appear to be injurious. The fact is that a certain amount of fretful fermentation requires to be constantly

kept up in these beers, in order to maintain that brisk-ness of condition, and close permanent head, which is demanded by the consumers. The presence of starch favours the maintenance of this fretfulness, which although ruinous to ales, is positively advantageous in the case of black beers.

By adopting the precautions and the temperatures that I have indicated the brewer cannot fail to obtain from his malt as perfect a wort as it is capable of yielding, but it by no means follows that he will obtain the whole of the wort that can be extracted.

Careless brewers often say that they do not want to get the largest possible extract from the goods, but it would be generally nearer the truth if they confessed that they were too indolent or ignorant, to do justice by the materials they had to operate on. Of course there is a limit to the economical and advantageous washing of the goods, and this is probably reached, when after slow and careful sparging, the gravity of the wort flowing from the taps falls below 1004° spec. grav. or say 1·5 lbs. per barrel, at 60° F. Provided this limit is not over-passed the larger the extract obtained the better, at any rate from a commercial point of view. The only exception I would make is in the case of first-class stock and export ales when perhaps a limit of 1006 spec. grav. is low enough.

It by no means follows that because the wort running from the taps is as low as 1004° spec. grav. when the last of it is run to the copper, that therefore all the valuable extract has been obtained from the goods, for if the sparges have been run on rapidly and carelessly, a portion of the goods may still remain saturated with a much heavier wort. Under such circumstances as great

a loss occurs, as if the brewer had deliberately run so much wort down the drain.

Spargers also, in bad condition are a fertile cause of such loss of wort, for they sprinkle the water unevenly over the goods, and so leave a large portion only partially washed. And not only does a heavy loss occur under these circumstances, but as that portion of the goods on which the great bulk of the water falls, must necessarily be over washed, there is a loss in the quality as well as in the quantity of the extract ultimately obtained.

The worst instance of defective spargers I ever came across was in one of our largest breweries. In this case the spargers threw the great bulk of the water on less than half the area of the mash surface, and the loss of extract, which was about ten per cent., amounted in money value to many thousands a year.

Even with perfect apparatus many brewers fail to get all the valuable extract out of the goods, and the main cause of this is, that they run the sparge on and the worts off too rapidly.

I cannot lay down exact rules applicable to every case, but I may say generally that it is impossible to extract all the wort from the goods in less than four hours from the time of setting tap, and an even longer time is necessary in some cases, and especially when a considerable proportion of unmalted grain is used.

Three quarters of a barrel per quarter is quite enough to run off in the first hour, and this speed may afterwards be increased gradually until it is about doubled.

Some brewers sparge on the water throughout at the same speed as they draw off the wort, so as to keep the goods always at one level until all the water is on. Others stop the sparge and run off nearly all

the wort once at least, if not several times during the sparging.

For light beers the former plan is, I think, the best, but when, as in the case of heavy beers, the extract has to be obtained in as small a bulk of wort as possible, I prefer to run off all the wort that can be obtained perfectly brilliant at least once; and also to partially draw off the wort, so as to get the goods into a small compass, several times. After drawing down the goods to any considerable extent, it is always advisable to close the taps for a short time, and when the wort has been run off very close, it is sometimes useful to run the rakes once or twice round the tun; but with a perfect mash the too frequent use of the rakes is to deprecated. I need scarcely add that before the rakes are set in motion the brewer must close the taps and also ascertain that a sufficient amount of water has been run on, and, of course, after using the rakes the taps must be kept closed until the worts will run bright again.

The principal difficulties with which the brewer has to contend in the stages of the process described in this chapter are, the flooding of the goods, accompanied by more or less imperfect drainage; and the production of a wort which is deficient in brilliancy.

The flooding of the goods and imperfect drainage, arise mainly either from an excessive proportion of fine floury matter existing in the grist, or from an excessive stirring of the goods. In the latter case the obvious remedy is to stir the goods less, and if it is found that shortening the period during which the rakes are in operation involves the formation of balls, and the imperfect amalgamation of the malt and water, the speed of the rakes must be increased, or an outside masher added to the plant.

When there is too much flour in the goods the malt must not be ground quite so fine, and in mashes in which only ordinary malt is used, this remedy is always effectual. When, however, ungerminated grain is employed, in addition to the ordinary malt, it is not always possible to grind the latter coarsely enough, without excessive loss of extract, to counteract the superabundance of fine particles in the non-germinated grain. This latter, when prepared by simple kiln-drying and grinding, always contains too much flour, to allow of any considerable proportion of it being used in the mash, without obstructing the drainage. Some manufacturers have resorted to the costly expedient of sifting out the finest flour, and only supplying the brewer with the coarser particles. This is evidently a wrong principle to work upon, as the fine flour is exactly the chief extract-yielding portion of the grain.

The true remedy is to crush the grain in such a manner as to break up its structure thoroughly, without producing flour, and this I accomplish under my recent patent; I have already described my process in Chapter XV. A large proportion of grain so prepared can be used without injuriously affecting the drainage, and some such system must be adopted if the evils of flooded goods and bad drainage are to be avoided, while the numerous advantages derived from the use of a proportion of non-germinated grain are at the same time secured.

Cloudiness of the wort may arise from various causes and appear at various stages. The first wort which flows from the taps of an ordinary mash tun is nearly always cloudy, especially when internal rakes are used. This cloudiness arises partly from the presence of

particles of the mash, which have passed through the false bottom, and come away with the first rush of wort, and partly from the wort having been reduced in temperature by contact with the cold bottom of the tun. If the cloud arises from these causes only it is not of much importance, provided the wort becomes brilliant after a small quantity has run off, and the cloudy wort is returned to the top of the goods without disturbing them.

If, however, the goods pass through with the wort for a considerable time, means must be taken to correct this mechanical fault, which arises either from some defect in the false bottom, or from the mashing machine working too close to the plates and thus forcing the goods through them; an accident particularly liable to occur when indiarubber pieces are affixed to the ends of the rakes.

There is another form of cloudiness which is quite independent of mechanical imperfections, and is a much more serious matter than the mere mechanical presence of solid particles in the wort. This dangerous symptom manifests itself as a sort of opalescence, such as is always seen more or less in unboiled wort after it has cooled. This opalescence in the hot wort generally indicates either that too high heats have been used at some period of the mash or sparge, or, what is more serious still, it may arise from excessive unsoundness in the malt or other materials that have been used.

I have not alluded to the setting of the goods as a possible accident, because although liable enough to occur in former days, before thermometers were used, it would now be an insult to the youngest brewer to suppose him so utterly ignorant of the first principles of his business, as to be capable of making such a mistake as could lead to so untoward an accident.

Having now gone fully into the process of obtaining a wort by the ordinary English infusion process, I will next give the details of the decoction process, so generally preferred on the continent.

The German, or decoction method of mashing is certainly a very perfect system, and, with a well-arranged plant, it does not involve very much more trouble and attention than our English system. The decotion method however, requires a much more expensive plant than our infusion process, but, on the other hand, it yields about five per cent. more extract than we can obtain.

I have already, in Chapter VIII., described the best form of decoction mashing plant. The process varies somewhat in different localities, but the following is an accurate description of it as carried out in some of the best breweries.

The ground malt is first mashed with cold water through the automatic masher at the rate of two and one-third barrels per quarter into No. 1 tun, and an additional supply of water at the rate of one and a quarter barrels per quarter is heated to the boiling point in No. 1 copper. The rakes are then started in No. 1 tun and kept revolving at a good speed throughout the following operations. The boiling water is now pumped very slowly from No. 1 copper into No. 1 tun until the heat of the mash stands at from 95° to 100° F., this will still leave a little water in No. 1 copper. As soon as the heat of the goods has reached the above point in No. 1 tun the pump is stopped and one-third of the mash is run to No. 1 copper heated very slowly to 145° F., and then more quickly up to the boiling point and finally boiled for fifteen minutes.

The pump is now started again and this boiled mash

slowly transferred to No. 1 tun until the heat of the mash is raised to 127°, at which it is allowed to remain fifteen minutes, a little boiled mash being left behind in the copper. One-third of the mash is then again run to No. 1 copper, heated to the boiling point, boiled fifteen minutes, and pumped back to the tun until the heat of the mash is raised to from 145° to 149°

Up to this time the rakes have been going nearly the whole time in No. 1 tun, they are now stopped and in such a position as to prevent, as far as possible, the goods from reaching the pipe which communicates with No. 1 copper. After standing a few minutes, most of the thin but muddy wort is run to the No. 1 copper, as free from goods as possible. This muddy wort is boiled for half an hour, and then the rakes having been again started, it is pumped back to No. 1 tun, until the heat of the goods is raised to 167° F.

Whatever mash may be left over in No. 1 copper is pumped to No. 2 tun, the false bottom plates of which have been previously just covered with nearly boiling water.

The temperature of the contents of No. 2 tun is then noted, and as soon as it has fallen to 167°, the whole of the contents of No. 1 tun are at once pumped to it, the rakes in No. 1 tun being kept going, and that tun itself finally rinsed with water, so as to insure all the mash being transferred to No. 2 tun. The rakes in the latter are then run once round in order to level the goods, and the mash allowed to stand for three-quarters of an hour.

During these various operations every precaution is taken to prevent No. 1 copper and its contents from burning. As I have said, a little of its contents are always allowed to remain behind when the bulk is

pumped to No. 1 tun, and the fire is drawn forward and damped every time. When the last of the boiled thin mash is transferred to No. 2 tun this copper is quickly rinsed with water, the sluice turned off, and water run in until it is safe. In spite, however, of all precaution some burning of the goods and copper is apt to occur, and I do not hesitate in saying that No. 1 copper certainly ought to be heated by means of a steam jacket, and not by direct fire heat.

The mash in No. 2 tun having stood for three quarters of an hour the taps are set to run into the wort trough with the connections from the latter open towards the pump, but closed towards No. 2 copper. The wort as it runs off is returned by means of the pump to the top of the mash, until it flows perfectly brilliant from the taps. As soon as this is the case the connection with No. 2 copper is opened, and that to the pump closed, and the brilliant wort run into that copper.

The sparging is conducted with the tun open ; in fact, throughout the operations the tuns are seldom, if ever, covered. The water is sparged on, at, or near the boiling point.

The temperature of the sparge is not of the same importance that it is with our system of mashing, for as every particle of starch is converted, there can be no formation of soluble starch, even if the water is boiling. The total amount of sparging water used is generally about equal to that used for mashing.

Owing to the amount of stirring they have undergone, the goods are always somewhat heavy, so that they have to be stirred with the rakes several times in the No. 2 tun.

The taps are, of course, closed while the goods are

being stirred, and when they are opened again the same precautions are adopted for securing perfect brilliancy in the wort run to No. 2 copper, as in the case of the first wort.

The decoction system of mashing is an excellent one, but I doubt whether the extra five per cent. of extract obtainable by it, will prove a sufficient inducement to any of the brewers of this country to alter their plant. If the system was one adapted for mixed grists of malt and non-germinated grain, I should strongly advocate its adoption, but it appears to me to be essentially an all malt system of mashing, and as there is another system by which the extra five per cent. of extract can be obtained from the malt, and a large proportion of non-germinated grain can be successfully employed, it appears to me that this other system is much more worthy of adoption than the decoction process.

The system I have just alluded to is that invented by the well-known American brewer, Pigeon, and known by his name. In Chapter VIII. I have already described his apparatus, the results obtained in which, when worked on his system, are really most remarkable.

As I have already said, the largest possible extract can be obtained from malt by the Pegeon process, and, at the same time, half the grist may consist of non-germinated material. Even with this small proportion of ordinary malt, the convertion is always perfect, the drainage as good as with an all malt mash, and the beers all that can be desired.

These are not theoretical results, but absolute facts. In America, an enormous amount of beer is brewed on the Pigeon system, and in his patent converters, and, in this country, the system has been thoroughly tested, and

proved to be a great success. One brewery in the south of England has now been working for four years on the Pigeon system, and the proprietor tells me that for two years he has neither changed his yeast, nor had a single brewing that was not satisfactory.

I am not at liberty to publish the details of the Pigeon system. The exact temperatures, &c., used in the converter are a secret which I am bound only to divulge to the Licencees working the patent converters. All I can say, therefore, is that the method of working is in strict accordance with the teachings of the correct theory and practice of the mashing process.

There are several other forms of converter but none in my opinion equal to the Pigeon. In Chapter VIII. I mentioned a simple and effective converter introduced by R. Ramsden and Son, which has the important merit of being I believe the cheapest in the market. The following is the process of working this converter:

I will take for an example a ten quarter mash, the grist being seven quarters of ordinary malt and three quarters of non-germinated material, and the apparatus consisting of a Ramsden Converter with a close steam coil or jacket and an ordinary mash tun with rakes and no outside masher.

I commence operations by grinding into the grist case commanding the converter the three quarters of ungerminated grain with one quarter of the ordinary malt, the remaining six quarters being ground into the grist case belonging to the mash tun. I then run into the converter fourteen barrels of water at 140° F., and having started the stirrer at full speed I mash in the above four quarters of mixed grist. As soon as the grist and water are thoroughly mixed I turn on the steam to the con-

verter, and keeping the stirrer going at a sufficient speed to maintain a perfect admixture of the grist and water, I gradually raise the temperature of the whole to the required point. When this is reached the steam is turned off and the stirrers are kept going for fifteen minutes longer in order to allow the coil or jacket to cool, and cold water may be also introduced into them for the same purpose.

The exact temperature to which the contents of the converter should be raised, and the time taken in effecting the operation depend on the character of the ungerminated material used. I may state generally that with barley, wheat, and rye it is only necessary to raise the temperature to about 180° in the course of from one to two hours. Maize and rice on the other hand require a temperature approaching the boiling point, and three hours is not too long a period if the best results are to be obtained from the operation.

If a temperature of 180° has not been exceeded, the mashing operations may be at once proceeded with, and completed, but if maize or rice are the materials employed, it is generally better to carry out the above first portion of the process during the afternoon or evening, so as to give time for the boiled mash to cool spontaneously during the night, and thus to avoid the necessity of adding an excessive quantity of cold water to it.

In order to cool the contents of the converter from 180° to the temperature at which it is advisable to mix it with the rest of the mash in the mash tun, about two barrels of cold water is run in and the whole well stirred.

The six quarters of malt are now mashed in the mash tun with ten barrels of water at 150°, and the rakes kept

going for ten minutes after all the malt is in the tun. The rakes are now stopped for fifteen minutes, after which they are again started at full speed, the contents of the converter run into the mash tun, and the converter rinsed down with a little hot water. The rakes are then kept going slowly for ten minutes longer, and the mash is complete.

With rice and maize it is sometimes advisable to mash a sack or two of the ground malt into the converter after its contents are cooled so as to reduce them to a thinner consistency, and thus facilitate their transfer to the mash tun.

Of course the experienced brewer will be able to slightly modify the mashing process in order to meet his requirements, and the characteristics of the special materials which he employs, but the rules I have laid down and the temperatures I have given in this chapter will be found to be a safe guide in all cases, and whether the grist is composed of ordinary malt only, or of various mixtures of it with non-germinated materials.

CHAPTER XIX.

BOILING AND COOLING.

AS the wort flows from the mash tun it is received either directly into the copper, or into an intermediate vessel called the underback. The former plan is only admissable where the boiling is accomplished by steam heat; with coppers heated by the direct action of fire, a sufficient supply of wort must always be ready to "save the copper," as it is technically termed, that is to say, to be discharged into it in the course of a few seconds the instant it is emptied, so as to prevent its burning.

The wort in the underback is in a condition that causes it to be more prone to change than at any other period. This change may be in two directions. If the temperature is maintained at from 130° to 160°, the diastase of the wort will continue to act upon its dextrine, and convert it into sugar; if, on the other hand, the temperature falls below 130°, or even, under some circumstances, at slightly above that point, injurious fermentative action, of an acid, or putrid character, is liable to be set up, unless the temperature is reduced to a very low point indeed. At a temperature of 40° or under, it is possible to keep the worts unchanged for a very considerable period, and this

same object is accomplished by raising the temperature to from 170° to 180°. It is scarcely necessary to point out that the latter is the preferable, and, indeed, the only practicable method by which the brewer can secure the worts from change.

In many cases, however, the brewer wishes to effect a certain amount of change in the wort after it leaves the mash tun, by continuing the action of the diastase, and this can be easily effected in the underback, if it is provided with a steam coil, or a steam or water jacket, capable of maintaining the wort at a temperature of from 150° to 165.

Under these circumstances, the wort may be allowed to remain for a certain time in the underback, but, if the latter is not provided with an efficient heating apparatus, the wort must in all cases be transferred as rapidly as possible to the copper.

Great care must be taken that small quantities of wort are never left in the underback or other receptacle, for injurious changes may very possibly occur, even during the two or three hours that the first worts are boiling, if every drop of unboiled wort that has run from the mash tun, does not find its way at once into the copper.

The stewing of the wort, that is, the maintaining of it at a temperature of from 150° to 165°, may be as well accomplished in the copper as in the underback, whether the copper is heated by steam or by direct fire heat.

This stewing is often advantageous, especially when the malts are deficient in diastatic power. When the fermentations flag, towards their close, and there is a difficulty in securing a sufficient attenuation of the beers, stewing is one of the remedies that may be tried, and often with considerable advantage.

The temperature of the wort, as soon as it reaches 150° should be raised slowly, so that, during the time the copper is being filled, the temperature may gradually rise to 165°. As soon as the copper is made up, the heat must be raised as rapidly as possible, so as to avoid any unnecessary delay. Of course, a less degree of stewing may be sufficient, in which case the time during which the wort is kept at or below 165° may be shortened.

When the malt is of first-rate quality, no stewing is necessary, or even advisable, and, as soon as there is a sufficient amount of wort in the copper, heat should be applied, and so maintained that the contents of the copper come to the boil a few minutes after the latter is made up. When a considerable proportion of sugar is used, the wort should always be brought to the boil as soon as possible, so as to preserve the full percentage of the dextrine of the malt wort.

The period at which it is most advisable to add the hops to the wort in the copper is a point on which there is a great diversity of opinion and practice. In Burton the whole of the hops which it is intended to add, are introduced before the copper comes to the boil, and are consequently boiled during the whole time.

Many brewers however prefer to add only a portion of the hops at first, and to reserve some of the finest new hops, which they only introduce into the copper shortly before its contents are turned out. This latter plan undoubtedly enables the brewer to retain a much larger proportion of the fine aroma of the hop in the beers, without an excessive amount of bitter, than when the whole of the hops are put in at first. When, therefore, a brewer has to use a water which tends to the rapid solution of the principles of the hop, I advise him

to only introduce a portion of the hops when he commences to boil the worts, and to reserve some of his best new hops, and only add them to the contents of the copper fifteen to thirty minutes before he is going to turn out. This plan will also often enable the brewer to dispense with dry hopping, at any rate in the case of those ales which are to come quickly into consumption.

Some few brewers boil the wort for a certain time before adding any of the hops. I think this practice is only advantageous when for any reason it is found necessary to boil the worts for an excessively long time, or say more than two hours.

When the whole of the wort of one brewing is to be boiled at once, no other questions can arise on the point I am treating than those I have already disposed of, but in the much more common case of about half the wort being boiled first, and then the second half, a first and second wort being thus made, there is the further question whether the whole of the hops are to be boiled in the first wort, and then returned into the second wort, or whether the hops are to be divided between the two worts.

In deciding this question several points have to be taken into consideration, viz.: the total amount of hops that are to be used; the character of the water as a hop solvent; and the quality of the malt liquor it is intended to produce.

The largest amount of soluble matter is extracted from the hops by boiling the whole of them in the first wort, and returning them all to the second; and for black beers, as well as common running ales, this plan is almost universally adopted.

The harder the water the less solvent power it has on

the hops, and consequently boiling the whole of them twice over is not so liable to produce a harsh bitter in the beers brewed with hard as in those brewed with soft water.

Twice boiling the whole of the hops is admissable with hard waters in even the finest class of mild ale where the proportion does not exceed 10 or 12 lbs. per quarter of malt used. Where, however, 15 lbs. and upwards of hops to the quarter of malt are employed, as in the finest class of Burton pale ales, twice boiling is only admissable when the ales are intended for export, and their consequent age before consumption will be sufficient to soften the harshness of the bitter.

In pale ales which are intended to be consumed without going through the peculiar stage of secondry fermentation, which occurs in season-brewed ales during the later summer months, twice boiling the whole of the hops renders the bitter too harsh to please most palates. In this latter case a portion only of the hops, generally from one-half to two-thirds, is boiled with the first wort; the remainder are boiled with the second wort, and none are boiled twice.

With waters having more solvent powers, and for light bitter ales which are to come quickly into consumption, it is often advisable to boil the hops only once, even when not more than 10 lbs. per quarter are used.

Another plan of mitigating the harshness of the bitter arising from twice boiling hops, and which has considerable merit, is that of boiling the new hops only in the first wort, and returning these into the second wort, with the addition of the unboiled old hops or yearlings.

Various other modifications, such as returning the hops from the first wort after the second wort has boiled

for one hour, will suggest themselves to the experienced brewer. It is impossible to lay down hard and fast lines on this subject, as the taste of various localities differs enormously in the amount of bitter which it will tolerate, and even greater divergencies arise from the quality of the water and the length of time during which it is the practice to keep the beer before consumption. Every brewer must use his own judgment, and study to please the palate of the majority of his customers, remembering always that long boiling economises hops but gives the beers a harsh bitter, and that with short boiling more hops must be used, but with a corresponding improvement in the delicacy of the flavour of the beers produced, and in their keeping qualities.

As the hops from the first wort when drained in the hop-back still retain a large quantity of strong wort, some means have to be employed to avoid as much as possible a loss from this source, when the hops are not returned to the second wort.

In Burton the usual practice has been for many years to subject the hops to hydraulic pressure, or in small breweries to that of a screw press, and this plan is now generally adopted in breweries throughout the country.

A simpler plan is to run the second wort into the hopback, without removing the hops from the first wort. If the whole is allowed to stand for a few minutes before running to the coolers or refrigerators, the hops from the first wort are thoroughly washed by the weak second wort, and no more loss arises as far as the saccharine constituents of the beer are concerned than if the whole of the hops had been boiled twice.

One objection to this plan is, that the hopbacks in many breweries are too small to hold and efficiently

drain such a large mass of hops; another is that it involves leaving the hops exposed to the air in the hop-back for some two and a half to three hours. I am well aware of, and have always insisted upon, the great danger arising from this exposure of the hops for any lengthened period; but I scarcely think it will be found that even three hours' exposure under ordinary conditions will produce any appreciable evil.

Sparging the hops in the hopback, or in a special vessel like a mash tun, is a plan which has much to recommend it, and is one which I think should be more generally adopted.

When the hops are to be boiled only once in two or more coppers of wort, I generally divide them so as to give about an equal weight per barrel to each copper, but I boil the newest hops and those containing the largest proportion of oily matters in the strong first wort, and the older and weaker hops in the weaker worts. The strong wort has a greater power of absorbing the more valuable portion of the hop extract, and the weaker wort the coarser bitters. If only one quality of hops is used, a rather larger proportion should be boiled with the stronger wort, but this inequality must not be carried too far, and at least one-third of the hops should always be boiled in the weak wort.

The proportion of hops generally used in the copper, in the best known classes of beers are about as follows:

Finest class of Burton export pale ales	17 lbs. per quarter.
Ordinary first-class Burton pale ales	15 ,, ,,
Burton strong ales ..	10 to 12 ,, ,,
Burton mild ales ..	7 to 10 ,, ,,

London and country bitter ales	7 to 10 lbs. per quarter.
London four ale ..	4 to 6 ,, ,,
Export stout ..	14 to 15 ,, ,,
Double and single stout	8 to 10 ,, ,,
Porter	4 to 5 ,, ,,

The qualities most suitable for each class of malt liquor, I have already pointed out in the Chapter on hops, I need not therefore revert to that subject here.

At whatever period the hops are added to the wort, they should always be pressed under it and roused with it so as to wet the whole of them as quickly as possible, for if any hops are left floating in dry masses on the boiling wort, their volatile principles are carried off by the steam, much more rapidly than when they are thoroughly wetted and incorporated with the wort.

After the wort once comes to the boil the ebullition must be kept up continuously and as vigorously as possible. This is a most essential point, and one on which there is and can be no difference of opinion amongst experienced brewers.

The maintenance of vigorous ebullition during the whole of this part of the process is of great importance, not only to secure sufficient evaporation, but also the thorough accomplishment of those chemical reactions resulting in the solution of the valuable principles of the hops, and the separation of the coagulable nitrogenous matters.

It is probable that one reason why boiling by steam, is not on the average as effectual as boiling by the direct action of the fire, is that on the former plan brewers are apt to be content with a less vigorous ebullition, and the men can more easily shirk their work, than when the copper is heated by a fire placed under it.

In a well set fire copper, the heat although distributed over the bottom does not act uniformly on all parts. The result is that the wort is thrown violently upwards from the more strongly heated portions, and a good rolling boil is secured, which effectually prevents that creaming which is so troublesome and frequent an incident of steam boiling.

To prevent creaming and boiling over, and at the same time to secure vigorous and continuous ebullition, requires vigilant and constant attention from the copper-man. To aid him in this arduous work, various forms of fountain and cone have been introduced; and I decidedly advocate their employment, especially in small breweries where it is inconvenient to have one man constantly tied to the copper side.

It is at this stage of the process that the necessity for the aeration of the wort first comes into force, and a vigorous boil, especially when aided by a cone or fountain, insures a sufficient action of the air upon the boiling wort.

In domed coppers little or no aeration is possible, and hence they are generally rejected by ale brewers, although they are still preferred by many of the large porter brewers. Even in domed coppers, and for black beers, vigorous ebullition is essential if a sound beer is to be produced, for if porter and stout do not require aeration in the copper, the extraction of the hops and coagulation of the albuminoid matters is as essential in their case as in that of ales.

Great diversity of opinion exists as to the length of time during which ebullition should be maintained. Some brewers are satisfied with an hour's boiling for either the first or second wort, whereas others do not

consider thrice that time as excessive. My own opinion, supported by a large experience is, that from an hour and three-quarters to two hours for the first wort, and from two to two and a half hours for the second, are the periods that give generally the best results.

The wort and hops having been boiled together with sufficient vigour, and for the requisite period, are discharged into the hopback, the fire having been first drawn or the steam turned off, as the case may be. It is advisable to run the worts from the hopback as free from sedimentary matters as possible, for if a large amount of sediment passes forwards with the wort to the coolers and refrigerators, it must be either strained out afterwards, which involves a considerable amount of trouble; or some of it, at any rate, will pass into the fermenting tuns, and become ultimately mixed with the yeast, which is not desirable.

In order to obtain the wort from the hopback as free from sediment as possible, care must be taken in the first place to run the wort gently from the copper until the hopback plates are covered, and the air under them has been expelled. The copper discharge is then turned on full, and the whole of the wort run rapidly out, so as empty the copper as quickly and completely as possible both of hops and wort, the contents being kept roused as far as is necessary to ensure the discharge of the former. Wort or water is then instantly run into the copper in order to save it. The above details of this part of the process must be strictly followed in the case of fire coppers, but with steam heated coppers the whole of the hops are somtimes retained by means of a strainer, and in any case it is not important to discharge them entirely with the wort.

After the hops and wort are in the hopback, the whole should stand for fifteen to twenty minutes, to allow sedimentary matters to deposit. The wort is then run off at a moderate speed, and so as to obtain it as bright and free from sediment as possible.

I have already alluded to the necessity for the aeration of the wort, or in other words the absorption of oxygen from the air by it, while at a high temperature. This process commences in open coppers while the worts are boiling, and must be completed before the wort has been reduced greatly in temperature by the coolers and refrigerators. As the exposure of the hot wort to the air varies in amount according to the construction of the plant, the brewer must take means to insure a sufficient exposure. This is most easily done when the worts are pumped from the hopback to the coolers, for if the natural aeration is not sufficient, the pump can be allowed to suck a little air through a small cock on the suction main. When the plant is otherwise arranged, other devices, which will readily suggest themselves to the intelligent brewer, most be resorted to, but in all cases a sufficient absorption of oxygen by the hot wort must be insured.

A further obsorption of oxygen is necessary when the wort has become comparatively cold. With open coolers this was formerly secured in the most natural manner, and both for this reason and also as a means of removing sedimentary matters from the wort, the open coolers are no doubt very useful. When horizontal refrigerators are employed to cool the wort, so that it is but little exposed to the air while passing over them, and still more when the wort is passed through pipes as in Riley's and Ashby's refrigerators, I consider a certain

amount of cooler surface as almost essential. In such forms of plant, coolers can only be dispensed with if special arrangements are made to aerate the cold wort before it reaches the fermenting tun. This may be done by dashing the wort from some height into that vessel, or in various other ways; but no plan is so convenient. and effective as the exposure of the wort only three or four inches deep on coolers of sufficient size, and for a sufficient time.

Coolers may be safely dispensed with when vertical refrigerators are employed, and the wort run in a film freely exposed to the air, over their extended surfaces I advise all brewers who wish to dispense with coolers to erect some good form of vertical refrigerator, such as the improved Baudelot, and if there is not height enough between the copper and fermenting tun, a centrifugal or rotary pump will easily deliver the wort from the hop-back into another back, placed at a high enough level to command the refrigerator.

To sum this matter up very shortly, the thorough aeration of the wort before it arrives in the fermenting tun is essential, and the most simple and practical methods of insuring this aeration are to either expose the wort on shallow coolers, or on the extended surfaces of vertical refrigerators.

Provided the wort is sufficiently aerated it cannot be too quickly cooled, for long exposure, especially at temperatures between 70° and 130° F., is sure to cause more or less deterioration, and frequently injures the soundness of the beers, promoting fret and other evils. Coolers and refrigerators therefore should be provided of sufficient power to cool the whole of one brewing down to 58° or 60°, in six hours or less, even in the

hottest weather, reckoning from the time the first copper is turned out, until the whole of the brewing is in the fermenting tun.

The exact temperature to which the wort should be reduced, depends on the strength of the beer, the system of fermentation adopted, and the season of the year, or rather the temperature that prevails at the time.

The stronger the beer, and the warmer the weather, the lower the temperature to which the beer should be reduced, unless the means of attemperation are so ample that it is easier to govern the heat of the fermenting beer by means of the attemperators, than to reduce it to a very low point with the refrigerators.

I may say generally that 60° is the temperature to which beers of medium strength and in good brewing weather should be *generally* reduced. Strong beers in all ordinary weather should be reduced to 58 or even lower, and in summer weather the latter temperature may be adopted with advantage for all except the weakest beers.

The above are the most advisable pitching heats on the cleansing system, or in any case if there is a deficiency of attemperating power, but if the supply of cold water is constant and abundant, and the attemperators of ample power, the beer may be safely pitched all the year round at 60° or even higher, and the temperature during fermentation kept below 70° by means of the attemperators.

The idea that there is any risk in turning the cold water on to the attemperators in the earlier stages of the fermentation is a delusion. The practice is perfectly safe, and in many cases it is advisable to keep more or less water passing through the attemperators during the

whole period of the active fermentation. All sudden alteration of temperature must however be avoided, and it is generally advisable to allow the temperature to rise slowly and at as even a rate as possible.

Provided these precautions are not neglected, it is a perfectly safe practise to regulate the temperature of the fermenting beer by means of the attemperators, at any and every stage of the fermentation.

For the guidance of young brewers, I give in the following table a sketch of the times at which the various brewing operations will generally occur in a well regulated brewery, provided the mashing is commenced at six o'clock and the worts boiled at twice. I give the hours on the one to twenty-four system, which all brewers will find, if they will try it, saves time and trouble in booking :—

		Hour.		Minutes.
Commence mashing	at	6	.	0
Mash completed	,,	6	.	30
Set tap	,,	8	.	30
First copper up	,,	11	.	30
First copper boils	,,	12	.	0
First copper turned out	,,	14	.	0
Second copper up	,,	15	.	0
Second copper boils	,,	15	.	30
Second copper turned out	,,	17	.	30
All in collecting vessel	,,	19	.	30

If the whole of the wort is boiled at one time, a full hour can be saved without unduly hurrying any portion of the operations.

CHAPTER XX.

FERMENTATION.

I HAVE now come to what may be considered the final and most important stage of the brewing process, during which the sugar is converted into alcohol and carbonic acid, and what was wort, becomes beer. All the other stages of the process lead up to this, and the object of the care and attention I have insisted upon, is to produce a wort capable of undergoing the fermentative process in a satisfactory manner.

There is one great and essential difference between fermentation and all the other brewing operations, for it is in this stage alone that vital forces come into play. Yeast is a minute plant, and it is under the influence of the vital forces of this minute but active organism, that the sugar is split up into alcohol and carbonic acid and the wort converted into beer.

In this Chapter I propose to touch as lightly as possible upon the scientific aspects of fermentation, and to call the attention of my readers to practical details rather than to theoretical considerations. In the second part of this work I intend to go more fully into the science of fermentation as it occurs in breweries, illustrating the subject with original photographs, and drawing liberally

on the teaching of Pasteur and others, so as to enable the brewer to understand the scientific reasons, for the practical manipulations, which experience has proved to be essential to success.

In considering the practical details of the fermentation of beer, I shall commence with those that are common to all the various systems adopted in this country; and, in the second place, I shall consider the distinguishing features of each system, and the best method of working it.

Taking the processes in the order in which they actually occur in the brewery, the selection of the yeast first claims attention. The general condition and purity of the yeast should be constantly checked in every brewery by frequent microscopical examination. Long practice and experience can alone enable the brewer to judge with accuracy of the condition of the yeast, from its appearance under the microscope, and in the second part of this work I shall endeavour to aid him in acquiring the requisite knowledge.

I may say here that the cells should be fairly uniform in size, and that they should be plump and well filled out, the cell contents being like a clear fluid, slightly clouded, but free from granulations. There are always a few granular cells present in every yeast: they are those which have become aged, and are dead or dying. The worst of these cells have an irregular outline, and are evidently shrivelled. In a good pitching yeast there should be very few of them, and all yeasts in which they exist to any considerable extent should be rejected.

Then, again, the yeast cells of a good pitching yeast should be separate from one another. Of course they will appear agglomerated into mases, but there should

be no physical junction between the cell contents, for if the cells appear as budding one from the other, it is a proof of weakness. In the early stages of fermentation, the yeast cells bud, and multiply by budding, but as soon as this stage of multiplication is passed, the cells of a good yeast separate completely from one another, and each has a separate and independent existence.

The cells of the different varieties of yeast vary somewhat in shape. Thus the Burton yeasts generally contain a good many slightly oval cells, whereas the cells of most other yeasts are perfectly spherical in outline, but whatever their shape they must, as I have already said, be plump and well filled, and they should be fairly uniform in size.

Besides the appearance of the yeast cells, the brewer must ascertain that the yeast is fairly free from other organisms, and especially from those rods or bacilli which are ordinarily the active cause of beers becoming acid. These rods exist in various stages, the longer forms being apparently the most active agents of the lactic fermentation. All the forms are, however, objectionable, for although the shorter ones may not be promoting active mischief at the moment, the brewer must remember that they are always ready under favourable circumstances to develop into the active forms.

Besides the rods there are the various forms of microbacteria which probably produce stench in beer, and the presence of which in large quantities also indicates that decomposition has commenced in the yeast. A few of these minute organisms are nearly always present, but the number in a good yeast must be very small.

Then, again, there are the excessively minute cells of

micrococci, very difficult to distinguish from some sedimentary matters, and the presence of which often causes slow and imperfect fining. And, lastly, there is the micoderma acceti, or vinegar plant, a most deadly organism to beer, but one which carefully managed breweries seldom have to contend with except, perhaps, in an occasional cask. The cells of this organism are remarkable for their extreme minuteness and transparency, but the careful brewer will detect its presence from the pungent smell of acetic acid, and acetic ether, which can at once be detected in all pipes, vats, casks, or other vessels where it exists.

The pitching yeast under the microscope should consist of yeast cells having the characteristics I have described above, and the spaces between the cells should be as nearly as possible free from all other organisms.

The yeast should have a pleasant smell, and should be of a pale uniform colour. Its consistency is not so important as many old fashioned brewers are inclined to think, but it must on no account have become thin by keeping. A yeast which is thin owing to being used very young before the beer has had time to separate from it, may be an excellent pitching yeast, and all that is necessary is to allow for the larger proportion of beer in it, by using a proportionally larger quantity. But a yeast which has been thick, and has become thin by keeping, is already in a state of decomposition, and should be unhesitatingly rejected.

The age of a yeast is a most important consideration in determining whether it is fit to be used for pitching ; and I may say generally, that the younger a yeast is the better. As an illustration of what I mean, and of the limits of age that are permissable, I will take the Burton

cleansing system. On this system the beers usually remain from thirty to forty hours in the fermenting-tun, and, dating the age of the yeast from the time of cleansing, the general rule is to reject all yeast that is more than five days old, or, in other words, that is more than a week old, reckoning from the time of mashing.

Of course temperature has a very considerable influence on the length of time during which yeast can be kept without deterioration. In warm summer weather it is safer to reject all yeast which is more than four days old from the date of cleansing; whereas the age may probably be safely extended to six days in cold and clear winter weather.

I have given this illustration as a general guide to the brewer, as it is impossible within moderate limits to give exact rules applicable to every modification of the fermenting process. This much, however, is certain, that the earlier the period at which the yeast is used again after it has separated from the beer, the less liable it is to deterioration.

Many brewers imagine that the yeast plant requires a period of rest between each fermentation. This is, I think, a great mistake; the period of so-called rest is one, in fact, during which the yeast deteriorates for lack of nutriment, while the rods, bacteria, and other organisms, grow and multiply vigorously at its expense. There is no more nourishing food for these ferments of disease as Pasteur calls them, than that derived from the inactive yeast cells, which can only protect themselves against the attacks of their enemies, when they are in a state of active nutrition.

I have so far pointed out the physical and microscopical characteristics of a good pitching yeast, but

however good and pure a yeast may appear to be, it does not follow with absolute certainty that it will produce a beer of first-class flavour. There are some yeasts which have a natural tendency to impart what is known as "yeast bite" to the beers fermented with them, and the process in some breweries appears to favour the development of a yeast having this most objectionable characteristic.

The Scotch ale breweries have always exhibited this peculiarity, and I am inclined to attribute this fact to the deficient aeration of the wort and beer in the Scotch system of brewing and fermentation.

That the defect is in the yeast, is at once proved by the effect of a change obtained from a brewery where the flavour of the ale is good. Such a change of yeast, without any other alteration in materials or process, will at once correct the tendency to yeast bite, and subsequent brewings of ale will for weeks, or even months, maintain the purity of flavour and freedom from all yeastiness, which characterised the ale from which the change was derived. Sooner or later, however, the yeasty flavour begins again to make its appearance, and another change of yeast becomes necessary in order to get rid of it.

I believe the cure for defective flavour derived from yeast, must be sought, and will be found, in a system of efficient, but not excessive, aeration and agitation. Certain it is that one seldom if ever finds yeast bite in beers that either by systematic rousing, or by cleansing, are kept in motion, and provided with a moderate supply of air during the later stages of fermentation. The supply of pitching yeast should always be obtained from roused, or cleansed beers, and this is the only way

of securing a constant supply of a vigorous yeast, which may be depended on to give a beer of first-class flavour.

Of course every yeast will produce yeast bite, if through carelessness or ignorance it is left in contact with the beer after the conclusion of the fermentation, and especially if the beer is allowed to remain in contact with the yeast at a high temperature, but what I have been speaking of is not this accidental yeast bite, if I may call it so, but that persistent yeasty flavour which some yeasts impart to the beers, however carefully they are manipulated.

The quantity of yeast required to insure a sufficiently active fermentation, varies considerably in different breweries owing to differences in the process and materials. The limits of variation may be roughly stated to be from rather under one pound per barrel as the lowest limit, up to 4 lbs. per barrel for the strongest, and most heavily hopped beers.

The stronger the beer, and the more hop it contains, the larger is the amount of yeast which it requires, and *vice versa.* Thus a 20-lb. beer with 5 or 6 lbs. of hops per quarter, will require from 1 lb. to 1½ lbs. of yeast per barrel, a 24-lb. beer with 15 lbs. of hops per quarter will require from 2½ lbs. to 3½ lbs. of yeast per barrel, and the same proportion of yeast will probably be sufficient for a 30-lb. beer with 10 lbs. of hops. It is only the very strongest beers which can ever require as much as 4 lbs. of yeast per barrel, provided the yeast is good and vigorous.

It should be further borne in mind, that ammonia in the brewing water promotes the vigour of the yeast, and that consequently less yeast is required in breweries

using a water containing ammonia. Nitrates have exactly the opposite effect, and the beers brewed with waters containing them require a very heavy dose of yeast to insure a vigorous fermentation.

Hard waters have been supposed to check the action of yeast, but I do not think that we have any proof that this general statement is correct. The truth is that certain salts promote the growth of yeast, some are neutral, and others retard it. I have mentioned the two series of salts which have the greatest effect on the development of the yeast plant, viz: ammoniacal salts and nitrates. Phosphates and especially phosphate of potash, are essential to the growth of the yeast, chlorides are certainly not injurious to it. Of the sulphates, that of magnesia probably slightly promotes, and that of lime slightly retards the yeast. The alkaline sulphates are certainly injurious to ales, but whether from their action on the yeast, or from some other cause is not known.

As regards antiseptics, the mono-sulphites interfere but slightly if at all with the yeast, and provided only a small proportion of those salts is used at first, this proportion may be gradually increased without the necessity arising for any increase in the proportion of yeast used. Thus beginning with four ounces of mono-sulphite of soda per quarter in the mash, I have increased the quantity gradually up to twelve ounces per quarter without having had to alter the proportion of yeast used.

Bisulphites have a more active influence, and so also has salicylic acid. When either of these antiseptics is used it is generally necessary to increase the proportion of yeast considerably.

The system of fermentation adopted, only appears to influence the amount of yeast required, in accordance with the amount of agitation and aeration which it involves. When the agitation is vigorous, and the aeration sufficient, a minimum of yeast is required, whereas when there is little or no aeration, and the beers are not roused, an excessive amount of yeast must be added, to insure the attenuation of the beers to a sufficiently low ultimate gravity.

The following table gives an abstract of the circumstances which indicate that a large or small proportion of yeast is required :—

Indicating a large proportion of yeast.	Indicating a small proportion of yeast
High original gravity.	Low original gravity.
Large proportion of hop.	Small proportion of hop.
Presence of nitrates.	Presence of ammoniacal salts.
Deficient aeration.	Abundant aeration.
Deficient agitation.	Active agitation.
Large amount of antiseptics, especially bisulphites or salicylic acid.	Absence of antiseptics, or presence of monosulphites only.

The presence of recent organic matter appears to promote the growth of yeast, and it thus sometimes counteracts the effect of the presence of nitrates. Unfortunately recent organic matter also promotes the growth of the acid producing and putrifactive organisms in a still greater ratio than that of yeast.

The strength of the yeast—that is, the power of a given quantity of it to effect a definite amount of attenuation—varies with the gravity of the beer from

which it is derived, and also with the proportion of hops that have been used. As a general rule, the strongest yeasts are derived from beers of medium gravity. A large proportion of hops has a peculiar effect on the yeast, for it has been found by experience that if yeast derived from heavily-hopped beers, that is to say, beers brewed with more than ten or twelve pounds of hops per quarter of malt, is used repeatedly to excite fermentations in beers of the same quality, it rapidly becomes weak, so that after a very short time it is impossible to effect the necessary attenuation by its means. This same yeast, however, is capable of accomplishing its work effectually in beers with a much smaller proportion of hops.

This is a most important point for the consideration of the pale ale brewer, who employs hops in the proportion of from fifteen to sixteen pounds to the quarter of malt. A rule which has been found to produce good practical results is to use half pale ale with half mild ale yeast for each succeeding pale ale brew, the fermentation of the mild ales being excited by either pale ale or mild ale yeast, as may be most convenient.

Good yeasts for pitching may be obtained from beers of from eighteen to twenty-five pounds gravity, provided these beers are entire, that is to say, beers which contain the whole of the wort from one mashing; the yeast from party gyles should, as a rule, be rejected, especially that from the weaker beer.

The best yeasts are obtained from beers which are brewed from malt or malt and well prepared corn only. The addition of sugar, whether derived from the sugar cane or from starch, acted upon by acids, weakens the yeast. This last remark does not apply, of course, to

condensed wort, which is made from malt and corn only, and the addition of which therefore cannot alter the constitution of a wort produced in the mash tun of the brewery, from the same materials.

The use of even a very considerable proportion of a suitably prepared, but non-germinated corn, strengthens the yeast, and so does a proportion of condensed wort.

In selecting his pitching yeast, the brewer must further bear in mind that the yeast plant appears to require a constant change of soil, as it were, to maintain it in the highest state of vitality; hence one of the uses of what the brewer terms a "change of yeast." Each brewery can, to a great extent, secure this change of yeast within itself, provided a sufficient variety of malt liquors is produced. A very good change of yeast is effected by using yeast from stout for ales, and *vice versa*. This, in fact, effects a more complete change than from one quality of ale to another.

When the growth of a serious amount of false ferments is once established in the yeast of a brewery, and also when the yeast becomes incurably weak, or imparts a yeasty flavour to the ales, a complete change is often the only practical remedy.

Such a change to be effective must be accompanied with a thorough cleansing of the fermenting vessels, pipes, &c., by means of boiling water, steam, and antiseptics. All the old yeast must also be dispensed with, except in such cases as those in which simple weakness may be cured by marrying the new with the old yeast; this plan however is seldom advisable.

It is often, however, prudent to keep a store of the old yeast, until the new is proved to be superior to it.

Even after all precautions have been taken, no good

results can be expected from the new yeast unless it is fresh, sound, and free from false ferments. Hence the necessity for the greatest care in the selection of the yeast to be used to effect the change, and for obtaining it from the brewery in a perfectly healthy state.

On this point brewers are too apt to be guided by merely empirical rules. The microscope should of course be used in selecting a change of yeast, but even this precaution is not always sufficient. A knowledge of the materials used in, and the process adopted in the brewery from which the yeast is derived, is generally essential, and should always, if possible, be obtained.

It is useless for a brewer to expect good results from a change of yeast from a brewery using a water loaded with nitrates, if the reason of his requiring a change is that his own yeast has become weak and impure through the presence of those same salts in his brewing water. And, again, it is evident that to replace a yeast weakened owing to the use of an excessive proportion of sugar, by a yeast from a brewery using an equal proportion of that material, is absurd. Yet such absurdities are constantly perpetrated by brewers, who then wonder why the change of yeast has done them no good.

In selecting a change of yeast, the brewer need not enquire particularly whether it is derived from a brewery using a hard water or a soft water. It is however very important for him to know whether the amount of aeration, rousing, and agitation of the beer during fermentation in the brewery from which he gets his change, is about the same as in his own brewery. This information is essential as a guide to him in the manipulation of the yeast, and in working it without loss into his own system of fermentation.

Besides the selection of the yeast there is another essential preliminary which must never be neglected; I allude to the cleanliness of the tuns, pipes, cocks, &c., which constitute or are connected with the fermenting plant.

Before commencing to run the cooled wort into the fermenting tun, this vessel, and all its adjuncts and connections, must be ascertained by the brewer to be perfectly clean. Dirt and carelessness are among the principal causes of the deterioration of yeast, and I cannot too strongly impress upon the brewer, not only the absolute necessity of general cleanliness, but also the peculiar dangers arising from the presence of even very minute quantities of decomposed yeast.

Yeast, like other plants, will not decompose as long as its vital forces are in full vigour. The life of this delicate organism is, however, easily destroyed under certain circumstances, and then its peculiar chemical composition causes it, especially under suitable conditions of temperature and moisture, to decompose with extraordinary rapidity.

Owing to its highly nitrogenous composition, its putrefactive products are analogous to those of animal rather than vegetable substances, and are of the foulest character. They present a fertile soil for the growth of every species of false ferment, from those producing simple acidity to those which induce putrefactive change of the most disgusting character.

Nine-tenths of the evils arising in many carelessly-managed breweries may be traced to minute quantities of yeast which are not removed by washing, and the products of whose decomposition are ultimately brought in contact with the beer.

a plentiful use of boiling water, combined with constant and vigorous scrubbing, is the only true safeguard of the brewer—no amount of scrubbing with cold water is effective, and it is even necessary to supplement the use of boiling water by somewhat frequent washings with solutions of sulphurous acid, the sulphites, or other antiseptics.

Warmth and moisture are the conditions which principally favour decomposition, but neither of them is by itself effective in this direction. As a certain warmth must be maintained in a brewery, the only safe plan is to keep the vessels as dry as possible. I must therefore utterly condemn the practice adopted in many breweries of leaving the fermenting vessels in a damp state. If it is necessary to throw them out of use for some time, they are best left dry and freely exposed to the air. This, however, with wooden utensils, can only be safely done when they are of the best construction. In old breweries, keeping the vessels in a dry state is frequently quite impracticable, and in such cases it is best to fill the vessels with water, and on no account to leave them merely damp. If the vessels are of resinous wood, lime should be added to the water, but with oak vessels the lime must be used very sparingly, and never left long in contact with them, or it will cause the wood to perish rapidly.

After a vessel has stood for some time full of water, it must be thoroughly scalded, and repeatedly washed with sulphurous acid or bisulphite solution, before being taken into use again.

Soft, spongy places in the timber always become nests of false ferments. A spongy piece of plank should be cut out, and replaced with sound wood as soon as it is

observed. Bad jointing and fastening are frequent sources of mischief. Unless the joints are close and the fastenings absolutely rigid, so that the joints cannot open under the pressure of the liquid when the vessel is filled, these same joints will soon become infested with every imaginable false ferment. This is particularly liable to occur when fixed yeast boarding is used, for the joints between thin yeast boards are never perfect, and soon become loaded with decomposing yeast.

A little hard scale on the tun may not be objectionable, provided it is perfectly adherent and has a smooth face; but all rough loose scale must be removed or rubbed down to a smooth face. I ought rather perhaps to say that the formation of such a deposit ought to be as far as possible prevented by diligent attention to the thorough scrubbing out of the fermenting tun every time it is emptied.

All pipes must be examined, and they ought to be brushed out and scalded every time they are used. If, however the steam and hot water connections which I have recommended are adopted, the pipes need only be brushed out occasionally, provided they are steamed and scalded before and after every brewing.

All attemperators, skimmers, parachutes, cocks, and other fittings, must be thoroughly washed, brushed and scalded, and their cleanliness and that of every portion of the fermenting plant ascertained by personal inspection.

We will now suppose that the yeast is weighed up, the perfect cleanliness of everything ascertained, and the wort ready to flow into the fermenting tun through the pipe leading from the refrigerator.

The object of the brewer at this point should be to ensure the rapid growth of the yeast plant, and that this

rapid growth should commence at the earliest possible moment. This immediate and rapid growth is best promoted by mixing the yeast thoroughly with a small quantity of the wort at a temperature of from 65° to 75° F.

The rest of the wort is then run in at a sufficiently low temperature to cause the whole, when mixed, to stand at the desired point, but it is advisable to reduce the temperature gradually, so that the last wort run into the tun is the coldest, and thus reduces the temperature of the bulk to the required point.

Many brewers consider this to be of little importance, and frequently mix the yeast with the wort that first comes down, without noting whether it is at the proper heat. Now if it has run slowly, it may be at such a low temperature as to check instead of promoting the growth of the yeast; and any such check must, it is evident, be attended with many disadvantages.

Another plan, to which I strongly object, is that of gathering the whole of the worts into the tun before the yeast is added. This not only retards the commencement of the fermentation for some hours, but renders it very difficult to mix the yeast thoroughly and uniformly with the wort. Of course the tun-room men raise strong objections to having to keep the worts roused with the yeast during the whole period they are flowing into the tuns; but from practical experience I am perfectly sure that brewers will find great advantage from insisting on this being done.

The beer being all run into the fermenting tun its dip and average gravity are ascertained and entered according to the excise regulations. If the weather is very cold and the tun only a small one, it is often advisable to

cover it up closely for the first twelve hours, or until the fermentation is in active progress. In extreme cases also warm water may be passed through the jacket or attemperator, so as to maintain the wort at the required temperature. On the other hand, in hot weather and when it has been impossible to reduce the wort as low as is desired by means of the refrigerator, its action may be supplemented by the early use of the attemperator.

The range of temperature now generally adopted is from about 60, as the starting point up to 70° as the highest limit for beers of from about 18 lbs. to 25 lbs. Stronger beers require a greater range, which is obtained by commencing the fermentation at two, three, or even four degrees lower, and carrying it some four or five degrees higher, making the extreme range for the strongest beers from 56° up to 75° In warm weather it is usual to lower the starting point for all beers, so as to extend the ordinary range to from 58° up to 70°. If, however, the attemperators are capable of keeping the temperature well under command, I have already explained that this lowering of the pitching heat is by no means essential.

When working, however, on the cleansing system, and without attemperators, a gain of two degrees of range at the lower end of the scale, is undoubtedly a great advantage in warm weather.

Some brewers consider that they obtain more advantageous results by limiting the rise during fermentation within a much smaller range; and I know of some cases in which the heat is never allowed to rise more than 3° above the initial point of 61°.

I do not myself think that the advantages of this plan are very manifest. It considerably retards the fermentation, and so increases the amount of plant and

the size of the buildings required. I cannot say that I have discovered any compensating advantages either in the quality of the beer produced, or in the maintenance of the vigour and purity of the yeast.

On the other hand, in many parts of the country very much higher temperatures are employed, the initial point ranging from 65° to 70°, with an ultimate temperature of 80° and over.

Under this system the limits of safety are frequently overstepped, the growth of the disease ferments is encouraged, and many evils in consequence arise.

These high temperatures during fermentation are by no means so detrimental in the case of stout and porter, especially when required for immediate consumption. The antiseptic action of the constituents of the black and brown malts assist to some extent in preventing the growth of the acid ferments, and traces of acidity are also more easily tolerated in black beers than in ales.

Some brewers, who by means of powerful attemperators have full control over their fermenting temperatures, pitch at 65°, but never allow the beer to rise above 70°. This plan seems to answer well and I can see no objection to its adoption.

It is an important observation, and appears to be borne out by very general experience, that the yeast plant thrives best at the temperature to which it has been accustomed; but that, like other plants, it will after a short time, acclimatise itself.

Thus, yeast taken from beers brewed on the Burton system does not at first thrive well when the temperature is not allowed to rise above 63; and under these circumstances, a very large amount of bottom yeast is apt

to form. If, however, only that portion of the yeast rising freely to the surface is used for subsequent gyles, it will soon accommodate itself to circumstances, and again produce good results.

This appears to be the explanation of the curious fact that bakers generally prefer yeast from breweries where the temperature is allowed to rise considerably over 70°, this higher temperature being more in accordance with that which they themselves employ in making the sponge.

In healthy fermentations and in good brewing weather, each degree of rise in temperature will about correspond with 1 lb. of attenuation, so that a 22-lb. beer pitched at 60° will have attenuated to about 12 lbs. by the time the temperature has risen to 70°. By this time also, the head will have gone through most of its changes and a yeasty head will be about to make its appearance. It is at this period that the beer should be either cleansed, or that vigorous and systematic rousing should be commenced, at intervals not exceeding three hours in duration.

After this stage is reached, the general rule in all systems is to separate the yeast from the beer while the fermentation is still sufficiently vigorous to cause its perfect separation. The temperature must also be lowered gradually, and both this lowering of temperature and separation of the yeast must be carried on as quickly as is compatible with the attenuation of the beer to the required point.

The separation of the yeast and beer is effected in various ways, according to the system of fermentation adopted, but I will here call attention to a somewhat novel system which is very generally applicable.

Some time ago a few brewers adopted a plan which has since extended considerably, and which offers some advantages. The whole of the yeast being pressed immediately after the fermentation has ceased, and this pressed yeast used for pitching. This plan involves the necessity of the adoption of the most stringent precautions to keep the yeast press and its connections and adjuncts in a state of perfect cleanliness ; and there is this further difficulty, viz., that the yeast cells are frequently injured, and even burst, by the pressure they are subjected to. It is this injury to, and bursting of the yeast cells, which is one cause of the deterioration of the yeast, which so frequently occurs when it has been subject to a heavy pressure.

My brother, Mr. A. G. Southby, has recently perfected and patented an apparatus and system which obviates these objections, while securing the great and undoubted advantages accrueing from the rapid separation of the yeast and beer. On this new system the yeast is pumped either direct from the tun, or immediately it has been skimmed off, into special filter bags, by means of a rotary pump. In these bags the beer drains rapidly away from the yeast, and is at once returned to the tun, and the yeast itself is obtained in exactly the right condition for pitching a subsequent gyle within three or four hours after it has been skimmed off.

At first sight, it may appear to most brewers that the pumping of the frothy head must be a troublesome and tedious operation ; but this is not the case, for the act of pumping at once separates the gas, yeast, and beer. The gas passes off from the upper portion of the bags, the beer drains rapidly away from the yeast, while the pumping itself does not require more time than is ordinarily

occupied in removing the yeast by means of a parachute or other skimming apparatus.

The advantages secured by this system are that the beer which is thrown off with the yeast, is separated from the latter before it has had time to become yeast bitten, and the yeast is obtained in a fit state for pitching in the shortest possible space of time, thus securing both its strength and purity, for, as I have before explained, the quicker the yeast is used to excite a fresh fermentation, after it has been removed from a previous one, the better. This plan is equally applicable to all systems, whether of skimming or cleansing, and the pumps may be driven by either hand or power.

If it is necessary to keep the yeast for any length of time before using it for pitching, some sort of cold storage arrangement should be provided, especially for summer use. The most efficient plan is to have an ice safe, or small room, kept at a low temperature by means of ice or a freezing machine. In this room the yeast should be stored in shallow vessels, of only a few inches in depth, for it is impossible to keep yeast cool if it is in a large mass, owing to its being a very bad conductor of heat.

If yeast is stored in tubs, even if these are placed in a refrigerator, the centre of the mass of yeast is liable to heat, but if it is placed in shallow vessels, and these vessels are stored in a refrigerator at a temperature of 40° to 45°, the yeast will keep for many days without the slightest deterioration.

Another plan is to store the yeast in the shallow vessel with a double bottom, and with cold water circulating in the space between the two bottoms, which I have described in Chapter XI.

I have hitherto assumed that the yeast separates from

the beer in the fermenting vessel without any artificial assistance, but this is not always the case, and in many breweries a 'dressing' of some sort is required to insure a rapid and perfect elimination of the yeast from the beer.

Various dressings are used by different brewers, but I think that the best is composed of the finest and soundest wheat flour, mixed either with a proportion of salt or with some yeast stimulant, such as an ammoniacal salt, either alone or mixed with a phosphate.

Thus for every ten barrels of beer, one pound of fine wheat flour may be used, either mixed with four or five ounces of salt, or with three ounces of a mixture of ammoniacal salt and phosphate of potash. The flour and salts are well rubbed up together, and the whole roused into the beer as soon as the brewer wishes the yeast to begin to be thrown to the surface, or when the attenuation is about at one half the original gravity.

The above mixture of ammoniacal salt and phosphates may be dissolved in the wort or beer at an earlier stage, if it is desired simply to stimulate the vigour of the yeast.

The degree to which it is advisable to attenuate any malt liquor, depends on various circumstances and varies from rather above one-third to somewhat under one-fifth of the original gravity.

As a rule the stronger the beer, and the better the materials, the less proportional attenuation is necessary, and black beers should not be attenuated so low as ales. Strong ales of 30 lbs. and upwards need not be attenuated much below one-third, and the final gravities of stouts should be rather over one-third than under that proportional gravity. Fine pale and mild ales of 22 lbs. to

26 lbs. gravity, and brewed with first-class water, malt, and other materials, should be attenuated to one-fourth, or say a 22-lb. beer to 5½ lbs. and a 26-lb. beer to 6½ lbs. or 7 lbs. Lighter ales should be attenuated to about one-fifth, especially in warm weather. It may also be taken as a general rule, that the warmer the weather the lower it is necessary to attenuate the ales, and any imperfection in the materials also indicates the necessity for a very low final attenuation, so as to prevent as far as possible the ales kicking up, and becoming turbid in the trade casks, owing to a too vigorous secondary fermentation being set up.

Many brewers confine the term secondary fermentation to that excessive fermentative acition which sometimes takes place in the trade casks, and which even in the case of sound ales results in temporary cloudiness and sickness, and which when it attacks beers brewed with inferior materials, results in permanent deterioration and ultimate acidity. I cannot so limit the term, for some degree of secondary fermentation is essential in order to maintain the briskness of the beer. The object of the brewer should be, to attenuate his ales low enough to prevent excessive fermentative acition in the trade casks, but not so low as to cause flatness, by preventing that slow and moderate action of the yeast cells which remain in the finished beer, and which maintains that constant and equable supply of carbonic acid, which is essential to the briskness and condition of the beer.

An excessively low attenuation results in thinness, in poverty of flavour and in flatness, especially when the beers are young, and must therefore be avoided just as much as the opposite defect. This is more particularly the case with quick draught ales, which cannot be

allowed time to recover. Stock ales, even if attenuated so low as to drink thin at first, generally recover their fullness of palate after a time.

Black beers are required by the public taste to drink fuller than ales, and also to carry more head and to maintain a brisker condition. These requirements are secured either by a high final gravity, or by the addition of syrup or wort in the trade casks. On the other hand the public care little whether the black beers they consume are bright or otherwise, provided they are clean and free from all yeasty flavour, or any excessive amount of suspended matter. A tolerably vigorous fermentation going on in the trade casks therefore does not produce any ill effects in porter and stout while it maintains that thick creamy head, fullness of palate, and brisk condition which is so much in demand amongst porter drinkers.

I may here remark that malt liquors of all qualities before they are racked, should be cooled down to below 60° F., so as to enable them to retain as much carbonic acid in solution as possible, while they are being filled into the trade casks. Of course, a lower racking temperature is both possible and advisable in winter than in summer, but even in the hottest weather the beer should be cooled down to 60° F.

I have already alluded several times to the fact that a certain amount both of aeration and of motion is necessary during the fermentation of beer, in order to keep that fermentation healthy, by maintaining the vigour of the yeast. That organism requires a supply of oxygen, and this supply, during the earlier stages of the fermentation, is obtained from the air absorbed by the wort during its preparation.

When the yeast is added to the wort, it first of all

seizes on the free oxygen dissolved by the latter while passing over the coolers and refrigerators, and when that is exhausted, it gets a further supply from the oxygen which has combined with the wort during the boiling, and while it was still at a high temperature in the hopback, and when first flowing on to the coolers.

When the attenuation has proceeded downwards until it has reached to about half the original gravity, both these sources of oxygen are generally exhausted, and more must be supplied if the vigour of the yeast is to be maintained. This further supply of oxygen is obtained naturally on the cleansing system, at first by the fermenting beer rushing into the cleansing casks, and afterwards from the feed beer, which is always freely exposed to the air, both when mixed with the yeast, and as it is drawn off from it, and which introduces oxygen into the cleansing casks every time it is turned on. On the stone square system, the pumping and rousing effects the same object, and on the skimming system the necessary amount of air must also be supplied by means of some form of rousing apparatus. I must the more strongly insist upon the necessity of rousing beers on the skimming system, because this is a fact which is ignored by many brewers, although why they should imagine that beers require less aeration and rousing on this system than on others, I cannot imagine.

Yeast not only requires a certain limited supply of air, but vigorous motion is necessary in order to enable it to do its work effectually, and then to eliminate itself at once from the beer. For this reason those systems are to be preferred which give a vigorous motion to the beer, together with a small supply of air, and it is because simply pumping air into the beer gives it too

much oxygen in proportion to the agitation, that that expedient has not been successful.

As soon as the vigorous fermentation is over, all exposure to the air is injurious to beer, for any absorption of oxygen will then make it drink flat and poor, until that gas has been converted into carbonic acid by the yeast cells.

If Brewers would only remember these simple principles, and act on them, they would avoid many evils, and would dispense with those large shallow racking squares which are such a constant source of flat beers in the first place, and fretful beers later on, especially when used in combination with the skimming system.

I now come to the consideration of the various systems of fermentation, their peculiarities and the best methods of working each of them.

The principal systems of fermentation adopted in this country are:—

The cleansing system.
The skimming system.
The stone square system.

And there are also numerous modifications of both of the two first named systems.

The simplest form of the cleansing system is that in which the beer is cleansed directly into the trade casks, and this was a very common plan, especially in London, some twenty or thirty years ago. It has, however, been abandoned by nearly all brewers who, if they work on the cleansing system, have now in most cases adopted some modification of the Burton process.

On the cleansing system as carried out in Burton, the beer is pitched at the temperatures I have already indicated, viz: at from 57° to 60° F. If the fermentation

is healthy and the weather cool, the rise in temperature will closely approximate to 1° F. for each pound of attenuation.

Under these circumstances the head will have gone through its various earlier stages, by the time the attenuation approaches to one-half of the original gravity, and the temperature to 70° F. This point is generally reached in from 36 to 40 hours, if the fermentation is vigorous. In any case, at or immediately under 70° F., the beer is "cleansed," by running it into the unions or other small fermenting vessels. By this means the rise of temperature is checked, so that it never attains to much over the point named, so long as the rooms in which these unions, or small fermenting vessels, are placed can be kept at a temperature of from 45° to 50°.

The limitation of the temperature of the fermenting beer to 70° is an essential feature in this system, the only exception being in the case of the very strongest ales, in which a limit of 75° is generally considered admissible. During the summer months it was formerly the practice in Burton to cleanse beers at a very early stage—in fact, sometimes as soon as the fermentation was thoroughly established, and the heat had risen to 64° or 65°. By means of attemperators in the unions, however, perfect control is now attained over the temperature of the beer, and the process can be carried out in the warm months exactly on the same plan as in winter.

It will be understood that on this system there are no attemperators in the fermenting tuns, and during the colder months no attemperators are required at any stage of the process; but for summer brewing attemperators are fixed in the unions or other cleansing casks.

The flow of water through these attemperators must

be very carefully regulated, so as not to lower the temperature unduly or too rapidly before the fermentation has had time to run its course, the object being to imitate the natural process of attemperation effected by the action of air at from 45° to 50° on the external surface of the small fermenting vessels.

Now that freezing machines are brought to such perfection, it is a question whether it would not be better to construct all breweries which are intended to be worked on the cleansing system, on such a plan that the fermenting rooms could be kept at a uniform temperature of from 45° to 50° in all weathers. This is a matter well worth the consideration of wealthy brewers, and some two or three have already erected the necessary apparatus, and have been keeping down the temperature of their fermenting rooms by means of freezing machines, with more or less success during the past summer.

After the beer is cleansed the greatest attention must be paid to the filling up of the cleansing casks, if good results are to be insured. The first filling up should take place about four hours after the beer is cleansed, and the filling up must be repeated at intervals not exceeding three hours, until the vigorous portion of the fermentation is concluded. Two or three fillings up at longer intervals will then conclude this portion of the process.

Unless this regular system of feeding is adopted at intervals, which must not exceed three hours, bottom yeast will deposit in the cleansing casks, the attenuation of the beers will be irregular, and they will not fine or come into condition in the trade casks as they ought to do.

Some brewers use a continuous feed, but I do not think this plan is to be recommended unless special precautions are adopted to insure a bright feed. In any case, the beer

used for feeding must be at least as free from yeast as that in the fermenting vessels; and it is always advisable to feed with a finer beer if possible. Inattention to this point will render useless all other precautions, and it is only by employing every possible means to ensure a feed free from yeast that brewers can rely on obtaining ales which will deposit little or no bottom yeast, and fine naturally and rapidly without the use of artificial finings.

The ordinary Burton method of separating the feed beer from the yeast is to have a series of holes in the end of the yeast trough adjacent to and forming one side of the feed trough. These holes are closed with corks, and the attendant ascertains by trial at which holes the beer will run off free from yeast and opens them accordingly. A good deal of yeast is apt to find its way into the feed trough through these holes; this yeast, in good weather, and when everything is in first-rate order, soon settles down, and as the feed pipe to the unions projects an inch or so upwards into the feed trough the yeast is left behind when the feed is turned on. It is impossible, however, always to secure a bright feed in this way, and it is often necessary to draw the beer off from the yeast trough through a screw cock into tubs and allow it to settle, or else the yeasty beer is sent to the yeast press and a bright feed secured in that way. There is, however, one unfailing method of securing a bright feed, and that is by pumping the yeast from the yeast trough into Southby's patent filtering apparatus. In all but the smallest breweries the rotary pump, which forms part of this apparatus, can be driven by power, and the bags should be so placed as to deliver the beer direct into the feed trough. In this way a bright feed

will be absolutely secured with a minimum of labour and trouble, thus allowing a continuous feed to be used with safety.

In various localities the cleansing system is modified in several ways, and I have already, in Chapter XI., described the special form of apparatus used by my friend Mr. Clinch, of Douglas. The general working of his apparatus is so similar to that of Burton unions that I need not particularly describe it. The weak point in his plan of working is, that the feed being automatic no artificial means of securing a bright feed can be adopted, and everything depends on the tun room being kept at a temperature not exceeding 50°F., and on everything else being in perfect order.

The other modifications of the cleansing system are not of much importance, and consist generally in varying the period at which the beer is cleansed and the temperature at which the fermentation is carried on. On these points the rules which I have given above as adopted in Burton have stood the test of the largest and longest experience, and are those which I recommend for general adoption.

The skimming system next claims our attention and where it is adopted, the object should be to approximate as closely as possible to the natural results arrived at on the cleansing system.

On the former system the pitching and the earlier stages of the fermentation up to the time when the beer is ready for cleansing, are conducted at the same temperatures and proceed in the same manner as on the cleansing system.

When, however, the beer would be cleansed on the Burton process, on the skimming system, it must be

roused, and this rousing must be continued at intervals of three hours until the fermentation is completed.

If the fermentation is proceeding in a normal manner, the skimming of the beer need not be commenced until a distinctly yeasty head makes its appearance. As soon as that is the case the head is removed before each rousing, and its removal is effected either by means of parachutes or by skimming into yeast waggons placed in front of the fermenting tuns, or by Southby's patent skimming apparatus, which may be used either alone or in conjunction with parachutes or yeast waggons.

Whichever of the above plans is adopted, as much as possible of the beer which is skimmed off with the yeast should be separated from the latter, and returned to the fermenting tun, as quickly as it can be freed from yeast either by deposition or filtration. It is seldom that the yeast naturally deposits from these drawings with sufficient rapidity to allow of their being returned to the fermenting tun while the fermentation has still some vigour, and yet this is an important matter, for nothing removes the yeasty flavour from drawings so quickly as the yeast itself in an actively fermenting beer. Artificial means are therefore very generally and should be universally adopted for separating the yeast from the drawings, that is to say, if drawings are not altogether avoided by the use of Southby's skimming and filtering apparatus. If drawings are produced, the best plan is to pass them at once through a filter press and return the filtered beer to the fermenting tun.

The regulation of the temperature on the skimming system depends almost entirely on the attemperators. These must always be of ample power, and supplied with water at a uniformly cold temperature, and at a uniform

pressure; in Chapter IV. I have already described how these results are to be secured.

As on the cleansing, so also on the skimming system, the temperatures which give the best results, are a pitching heat of from 58° to 60°, according to the strength of the beer, then a gradual rise to about 66° or 68°, at which point the water is turned gently on to the attemperator. The heat may then be allowed to rise gradually to 68° or 70°, when the flow of water is increased so as at first to stop all further rise of heat, and afterwards to gradually reduce the temperature to 60° or under, so as to prepare the finished beer for racking into the trade casks. The speed with which the temperature is reduced must be left to the discretion of the brewer, as it varies according to circumstances, but all sudden changes should be avoided, and the heat so regulated as to assist in securing the desired degree of attenuation. As I have already pointed out, this system may be varied by pitching at, say 65°, and attemperating during the whole period of fermentation.

The modifications of the skimming system, which I have described above, are, I think, at the same time the simplest, the most economical, and the most efficient that can be adopted, but there are several other plans of working this system, all of which have their advocates, and some of which possess considerable merit.

A few brewers still adhere to the old plan of omitting the rousing which I have recommended above, and which is in my opinion essential to complete success. It will always be found that those brewers who finish their fermentations in a single fermenting vessel, and yet do not rouse, have to obtain constant changes of yeast, either from other breweries, or by working a portion of

their plant on the cleansing system, and using the cleansed yeast for pitching the beers that are to be skimmed. They thus prove by their own method of working, that the strength of the yeast cannot be maintained without rousing, that is to say, without motion and aeration. I have abolished this mixed system in several breweries, and replaced it by the rousing and skimming system, and always with most satisfactory results.

The only other modifications of the skimming system which merit attention, are those adopted in the Scotch ale breweries, and the Irish porter and stout breweries.

In these breweries two sets of fermenting vessels are employed, the one set commanding the other. The beer is first pitched and collected in the upper fermenting tuns, and when it is nearly ready to skim, it is run down into, and the yeast skimmed off from it in the lower vessels.

On this plan the beer is thoroughly roused and aerated by its transfer from the upper to the lower vessels, and for black beers the process seems to answer very well. Some of the Scotch ales also produced on this system are second to none in flavour, condition, brilliancy, and in all other respects, but unless the beers are roused in the fermenting vessels as well as by transferring them from the upper to the lower vessels, I find that there is a strong inclination in the yeast to deteriorate, and after a time the unpleasant yeasty flavour so often found in Scotch ales makes its appearance, and can only be cured by a change of yeast.

Attemperators are of course used in this as in all other modifications of the skimming system. If the beers are to be run early into the lower vessels, attemperators are only required in the latter, but if the fermentation is nearly completed in the upper vessels,

it is evident that attemperators must be fixed in both sets.

In Ireland, the black beers are nearly always cleansed early, and attemperated in the lower or skimming vessel only. These vessels being shallow and nearly filled with beer, a good supply of air is afforded, and splendid beers are produced, but I am not sure but that a little additional rousing is advisable, and it would certainly obviate that weakness of yeast not unfrequently complained of.

I now come to the description of the last of the three systems of fermentation, viz., the famous Stone square system, so universally adopted in Yorkshire and some adjacent counties, and for which the important advantages are claimed that, while economical in working, it produces a fuller beer in proportion to the original gravity than any other process of fermentation carried out in this country.

As may be supposed from its name, the construction of the fermenting squares and the plan of working them constitute the peculiar features I have to dwell upon. As regards the former point, I have already fully described these squares and the mode of building them, in Chapter XI.

In working on this system, the wort is run into the top square, and flows from it through the organ pipe into the bottom square, the valve being left open for that purpose. The bottom square is thus filled, three or four inches of wort is run into the top or yeast square, and the valve is then closed.

The yeast is sometimes added after all the wort is in the square, but the better plan is to add it in the same manner that I have recommended on the Burton system.

This is accomplished by mixing the yeast with some warm wort in the top square, and running it down through the organ pipe when first starting. A comparatively small proportion of yeast is required in stone squares, from 1 to 1¼ lbs. per barrel being sufficient for even fully-hopped beers brewed with hard water.

The worts having been run into the square and the yeast added, the fermentation commences in about twelve hours. When in full vigour and about twenty-eight hours after pitching, the head and beer in the top square are well roused together, the valve is then opened and the mixed head and beer run to the bottom square. As soon as it has run down the valve is closed, and this operation repeated three times more at intervals of two hours. At thirty-six hours after pitching, or eight hours after the first rousing, the pumping is commenced and seventy strokes are given. The beer thus raised from the bottom square is roused with the yeast and beer in the top square, the valve is then opened and the beer and yeast run down. The amount of beer that is raised each time into the top or yeast square is regulated by the number of strokes of the pump, which is always made of one uniform size, viz., three inches diameter with a stroke of six inches. The pumping commences with seventy strokes, which is gradually increased as the fermentation proceeds up to a maximum of 130 strokes.

This pumping, rousing, and running down are repeated until the necessary degree of attenuation is obtained. The square is then left at rest, and in the course of six hours the whole of the yeast separates from the beer and discharges itself into the yeast-trough. The valve is now opened and the square filled up with the beer that has separated from the yeast. The valve is then finally

closed, and any superfluous beer is run down and filtered, this filtered beer being afterwards mixed off at racking. The yeast is then removed and the manhole kept free from yeast by frequent skimming.

The beer, when bright enough, may be racked direct into the trade casks, but the more usual practice is to run it into settling squares and to rack from the latter.

The best range of temperature during fermentation in stone squares is from 62° F. as a pitching heat, and 68° or 69° as a maximum temperature. In cold weather it is often necessary to pitch as high as 63°, and also to run warm water into the jacket in order to ensure the fermentation starting within a reasonable time. This high pitching heat is rendered necessary by the small amount of yeast used, and the fact that on this system the vigour of the fermentation depends on a very large reproduction of fresh cells. When the fermentations are going well, as much as five times the amount of yeast used in pitching is often produced, which is a greater increase than occurs on any other high fermentation process.

In order to regulate the heat, cold water is run into the jacket at intervals during the fermentation, and as often as is necessary to maintain the above range of temperatures. About eighteen hours after the pump is withdrawn, and when the beer has become fairly free from yeast, cold water is turned on to the jact again, and the temperature reduced from the maximum to the racking temperature, which is preferred to be about 55° F.

There is one point I must allude to before leaving this subject, and that is the necessity of special precautions in order to keep stone squares free from false ferments.

With wooden fermenting vessels, the plentiful use of boiling water requires only to be supplemented by an

occasional wash with an antiseptic solution, such as that of sulphurous acid or bisulphite of lime, but it is not safe to apply absolutely boiling water to the surface of stone squares, as there is a serious risk of the stones cracking from uneven expansion.

Most antiseptics have an injurious action on the stone, dissolving the lime, destroying the smooth surface, and causing it to scale off. Alkalies are, therefore, our only resource, and these must be used in a caustic state, and of sufficient strength to dissolve and destroy all organisms and deposits. Either a solution of caustic soda or caustic potash may be used, and this is applied to every portion of the surface by means of a mop made of cotton or linen rags, and left on for from 12 to 24 hours. The square is then washed with water, and its surface well scrubbed with a bass brush, great care being taken to remove every particle of scale. If squares have been neglected they must be well rubbed with soft brick and fine sand until thoroughly polished.

I cannot conclude this chapter without some allusion to the German, low, or bottom system of fermentation, used in the manufacture of Lager Beer.

The peculiar feature of this system is that the fermentation is excited by means of a special yeast which is capable of vigorous growth and fermentative action at a temperature so low that the ordinary ferments of disease such as the Bacilli, Bacteria, &c., cannot develop.

The wort may be obtained either by the decoction or infusion process, or by any of their modifications, but the decoction process is generally considered to produce the wort best adapted for this species of fermentation.

Very few hops are used, generally not more than four-and-half lbs. to five lbs. per quarter. This small

quantity of hops is found to be sufficient for two reasons: first, because the antiseptic or preservative power of the hops can be to a great extent dispensed with, owing to the low temperature at which the beer is fermented and stored; and secondly, because the peculiar bottom fermentation always leaves much more of the bitter principles of the hops in the beer, than when a yeast is used which rises to the surface and consequently carries away with it a larger proportion of the coarser bitters, as in the case of our system of high fermentation.

The primary fermention in the Lager Beer breweries is carried on in cellars the temperature of which is maintained at about 40 F. by means of ice or of brine cooled by a freezing machine and circulating through a system of pipes suspended near the ceiling of the cellar.

The beer after passing over the coolers is cooled on a refrigerator by means of cold water in the ordinary manner to about 60°, and is then finally cooled down to 40° by means of a second refrigerator, through which either cooled brine or iced water is passed.

Small fermenting vessels of about twenty barrels capacity are generally used. These are filled nearly full of beer, as only a few inches of head rises to the surface in the earlier stages of the fermentation. Later on the yeast deposits on the bottom of the fermenting vessels, so that no yeast is skimmed off or removed in any way from the surface of the beer.

The temperature of the beer during the primary fermentation is maintained at about 40° to 45° F. This was formerly accomplished by means of shallow tin dishes, containing lumps of ice, and floating on the beer and hence called "Nageurs"; but in the more recently constructed breweries these somewhat clumsy "Nageurs"

are replaced by ordinary attemperators, through which a current of iced water is caused to flow.

This primary fermentation is completed in a period of from ten to fourteen days, and the beer is then run off from the fermenting tuns as free as possible from the yeasty sediment, and pumped to small vats, or, I should rather say gigantic, to casks, of about the same capacity as the fermenting tuns.

These casks are ranged in tiers on each side of the lagering cellars. In the best arranged breweries there are a number of these cellars, opening on to a common passage, provided at one end with a lift for the introduction and removal of the store casks. The casks in one of these cellars are filled up with successive brewings, which are distributed into a number of them, so as to promote uniformity of quality.

After all the casks in a cellar are filled, the beer is allowed to remain in them for from two to four months, and during this lengthened storage a slow fermentation takes place in the beer which gradually matures it. The beer gradually clears itself until it becomes perfectly brilliant, and when it is sufficiently matured it is run into the trade casks as it is required for consumption.

The lagering cellars are kept at a temperature of from 34° to 40 F., the former temperature being preferred.

The beer being brilliant, perfectly matured, and saturated with carbonic acid by the slow fermentation and at such a very low temperature, is in perfect condition for consumption the instant the trade casks are filled. In fact, when they are removed to the customers' cellars, and the beer is thus exposed to the ordinary temperature, deterioration sets in very rapidly and hence a quick draught is necessary, if the beer is to be consumed while

in perfect condition, except in the rare case of the consumer possessing an ice safe or cellar of his own in which to store it.

In order to obviate this difficulty, the beer is sent out in small casks, and the customers are supplied at frequent intervals, or else the beer is bottled. In bottle, Lager beer will keep good for about a fortnight under ordinary conditions and in moderately warm weather, but if it is required to keep for a longer period, it must he heated in the bottles or as it is commonly called, "pasteurised."

I may add that for the sake of cleanliness the fermenting tuns are usually varnished with shellac varnish, and both the lagering casks and the trade casks are pitched inside at frequent intervals, or in some breweries every time they are filled. Shavings of beech or some other tasteless wood are also introduced into the lagering casks, so as to give a place of attachment for the particles of yeast, the pitching of the casks having destroyed the natural surface of attachment which the wood would otherwise afford.

The lagering casks are removed from the cellars each time they are emptied in order that they may be washed and if necessary re-pitched, and the shavings are each time removed and thoroughly cleansed with boiling water.

Having given this brief sketch of the preparation of lager beer, I must in the next chapter return to the consideration of those final processes by which our high fermentation beers are finally prepared for consumption, after the close of the primary fermentation.

CHAPTER XXI.

SETTLING, RACKING, FINING, AND STORING.

THE primary fermentation having been completed, the beer has on all systems to remain at rest for a few days so that it may deposit the excess of yeast, which still remains in suspension, in it, before it is transferred to the trade casks or store vats.

This "settling" of the beer may be accomplished in the same vessels in which the primary fermentation has been completed, or in separate vessels, specially provided for the purpose.

Taking a general view of this question, I am persuaded that the strong objection which the brewers of a former generation had to moving the beer from one vessel to another, after the close of the primary fermentation was founded on sound experience, and is justified by a strictly scientific view of the question.

As will be seen from the preceding chapter, I am a strong advocate for suppying the yeast with a moderate but sufficient amount of air, and also for keeping it in a sufficiently vigorous state of motion during the primary fermentation, but as soon as this fermentation is con-

cluded I maintain that all access of air to the beer should be as far as possible prevented.

Access of air to the finished beer is always more or less injurious, at any rate for a time, and although many beers recover perfectly from the ill effects of the oxidising action of atmostheric air, it never does the beer any good, and may occasion permanent injury.

In Burton at the present time the great bulk of the beer brewed is fermented in unions so arranged that it must be run into large vessels commonly called racking squares, or rounds as the case may be, and it is from these that the beer is racked into the trade casks.

This however is not the original Burton system, for before the unions were introduced, and in some of the smaller breweries even at the present time, the fermentation is completed in loose hogsheads and the beer is racked from them direct into the trade casks, so that its exposure to the air is reduced to a minimum.

Cleansed beers however certainly stand exposure to the air far better than skimmed beers, owing no doubt to their being better charged with carbonic acid, or in other words owing to their having been less exposed to the air between the close of the fermentation, and the time of removal from the fermenting vessel.

Even cleansed beers however, would, I believe, be the better for not being exposed so freely to the air as they now are, during the time they are being run from the unions into the racking squares, or while standing in the latter.

In the case of skimmed beers the evil effects of exposure to the air in settling and racking squares, and while running into them is so evident and marked, as to be now very generally recognized, and it is not uncommon

to find breweries in which the large open racking vessels have been discarded entirely, and the beers either racked from the fermenting tuns direct into the trade casks, or the open racking vessels replaced by large casks or covered vessels of a larger size. All those brewers who have made this change are unanimous as to the great improvement it has effected in their beers.

Having given my views as to the principles which should guide the brewer in deciding on the method by which he will rack his beers, I will now give a description of the process as usually carried out, commencing with that adopted with Burton unions.

The size of the casks into which the beer is to be racked having been determined on, and also whether it is to be sent out for immediate consumption, or placed in stock, the first thing to ascertain is, whether the beer is in a suitable condition.

The smaller the casks, and the earlier the period at which the beer is to be consumed, the larger should be the amount of yeasty matter which remains suspended at the time of racking. It is only by experience that exactly the right point can be hit upon, but I may state generally that the fermentation having been in every way satisfactory, the beer is sometimes fine enough twenty-four hours after the fermentative process has quite ceased, to rack into kilderkins for immediate consumption. This is the very shortest time which must ever be allowed for the yeast to settle out of the beer, and it is only when everything in the brewery is in perfect working order, and in the best brewing weather, that beers can be expected to be fine enough for racking as early as twenty-four hours after the close of the fermentation.

For barrels and hogsheads a period of at least twenty-four hours longer must be allowed than when the beer is to be racked into smaller casks, and where the beer is intended for stock, or bottler's use, and is to be racked into hogsheads or butts, three or four days, or even longer, is necessary to allow it to deposit almost the whole of the sedimentary matter, so that it appears fairly fine and bright when examined in a small cone-shaped wine-glass.

The beer having been ascertained by inspection to be in the right state, the screw tap of each union cask is cleared by opening it freely for a second, and a sample examined to ascertain that the beer will run from every hogshead in the desired condition. The trough beneath the taps is then connected with the racking square into which the beer is to be let down, and the taps are turned on.

As soon as the beer is run out to the level of the projecting ends of the taps, these are carefully lowered one by one as long as it will run sufficiently fine. The trough is then disconnected from the racking square, the taps withdrawn, and the bottoms allowed to run into a tub, to be filtered or sent to the yeast press. In this manner the whole gyle is run together into the racking square in the required condition, and quite free from all bottom yeast. Perfect uniformity for each gyle is also secured, and if the different gyles brewed within a short period of one another are found to vary greatly in ultimate gravity, two or more can be run together so as to correct this defect.

Where loose hogsheads are employed, tap-holes are provided in their heads, and racking taps are driven into each hogshead. The beer in each is run into the trade casks separately.

I have more than once alluded to the importance of dry hopping in the finer class of ales, and we have now arrived at that stage when the dry hops should be introduced into the beer.

Before the hops are introduced it is most important to ascertain that every cask is perfectly sweet. The cooper is of course supposed to have assured himself that such is the case, but further security is obtained by every cask being smelt through the bung-hole after it arrives at the brewery, and immediately before the hops are introduced into it.

In various breweries different plans of dry hopping are in favour, but none can compare in simplicity and certainty with that adopted in the large Burton breweries

In these establishments the proportion of hops is weighed out separately for each cask by workmen who can be depended upon, and boys then introduce each parcel through the bunghole into the dry cask by means of a stick and filler. In this way every cask receives its equal and appropriate quantity. The proportions are from half-a-pound to the barrel, or somewhat less, for the finer class of mild ales, up to one pound and upwards per barrel for the finest pale ales.

The casks having been ascertained to be perfectly sweet, and the hops having been introduced, they are placed under the racking taps, a small canvas hose attached to the tap introduced through the bunghole, and the cask filled. The hops prevent any frothing, provided the racking squares are so placed that the beer is not run in under an undue pressure. Cork bungs with a bung cloth are inserted in the bungholes of the casks as fast as they are filled, and they are then rolled into the yard. After standing for a short time, the cork

bungs are withdrawn, the casks carefully filled by hand and securely shived.

When the skimming system is adopted, no racking square is absolutely necessary; all that is required is that one or more screw taps should pass through the bottom of the fermenting vessel, so that the fine beer, free from all bottom yeast, can be run directly into the trade casks by means of a hose affixed to each tap. I must here repeat my strong objection to all those arrangements of fixed taps and pipes so much favoured by many brewers, but which render it impossible to make sure of running the beer from the fermenting vessel free from bottom yeast. Even if small supplementary taps are inserted to enable the state of the beer to be ascertained, a certain quantity of yeast is sure to have collected in the main taps themselves. Neither is it always certain that because the beer runs clear at a small supplementary tap it will still do so when the main tap is turned on; on the other hand, fixed pipes are always liable to become reservoirs of decomposing yeast and other objectionable impurities.

The great advantages of racking the beer direct from the fermenting squares into the trade casks, are firstly, its simplicity, secondly, the economy it effects both in waste and labour, and thirdly, that it minimises the absorption of oxygen and the flattening of the beers which is so objectionable when they are required for immediate consumption.

The public taste, and especially in London, has so altered of late years that stock beers are but little appreciated, and new beers of from one to three weeks old are preferred for ordinary draught both in the private and public trade. As these new beers are consumed before

they have time to recover from any oxidation that may occur after the close of the fermentation, it is of the highest importance to rack them into the trade casks with as little exposure to the air as possible.

If racking direct from the fermenting tuns is objected to for any reason, the beer may be run into a close vessel of comparatively small size, and only capable of containing a small portion of one brewing. This vessel which I have fully described in Chapter XI, is supplied with beer from the fermenting tun by means of a pipe or hose, at the end of which, and fixed in the racking vessel, is a self-acting valve, which allows the beer to flow into the latter as it is racked and so as to keep it always full until the fermenting tun is empty. On this plan there is but little more exposure to the air than if the beer was racked direct from the fermenting tun, and the per centage of loss is scarcely increased at all.

Another excellent plan of effecting the above object is to run the beer from the fermenting tun into puncheons, placed on gantrees, as soon as the primary fermentation is over. In these puncheons the beer is topped up two or three times during the first 24 hours and is then loosely bung down until it is in a fit state for racking, when it is run direct into the trade casks. In cool weather this plan insures a very brisk beer and answers well, but in hot weather the puncheons should be provided with attemperators, or else placed in a cool cellar, as otherwise the beer may be at a higher temperature than advisable at the time of racking. Of course running the beer into puncheons involves a somewhat larger percentage of loss than racking direct from the fermenting tuns. The additional room required is also considerable.

Where the trade requirements are such that the beer

has to be racked absolutely bright, settling backs become necessary; but in this case, if rapid fining is to be secured, it is as essential that the beer should be run into them free from bottom yeast, as it is in those cases where it is run either into racking squares or direct into trade casks.

The difference between settling backs and racking squares is that whereas the beer is only intended to remain in the latter for a few hours, it may have to be left for some days in the former. For this reason, settling backs should be of sufficient depth to minimise the exposed upper surface of the beer in them, and they should also be covered down as perfectly as possible, so as to protect the beer as far as practicable from the action of the air, in fact they should be shallow vats.

This system of racking the beers bright into the trade casks from closed settling backs or shallow vats, was not uncommon at one time, but is now confined to a few country districts.

When beers are required to be racked bright into the trade casks, the more usual plan at present is to fine them in ordinary settling squares or in puncheons, and, if the beers are in good order, they can generally be racked perfectly bright in about twelve hours after fining.

The objection to this plan is that it generally makes the beers excessively flat, especially if they are fined in settling squares. To obviate this difficulty, and to get the beers quickly into condition, it is a common practice to add to them in the trade casks one or two pints per barrel of a syrup of 1150° spec. grav., and this plan generally answers well.

On the Scotch system, as I have already explained, the beer is run from the upper fermenting vessels into

lower ones, called skimming squares. In these the fermentation is completed, the beer is skimmed and settled, and then racked direct into the trade casks. The beer is often also fined in these skimming squares before racking, instead of the finings being added to it in the trade casks.

In the Irish porter and stout breweries all the black beers are generally vatted. Even if they are only to remain in the vat for a few days, they are transferred to it so as to suit the racking arrangements.

These beers are always "worted" in the trade casks; that is to say, a proportion of unfermented wort is added to them, the amount varying from half a gallon to one and a half gallons per barrel. Most of these beers have also a proportion of old vatted stout blended with them, so that they are a mixture of new stout, or porter, old vatted stout, or porter, and a small proportion of unfermented wort. I am now speaking of the stout and porter for immediate draught, and for this purpose the above mixture insures the fine creamy head, and excessively brisk condition required by this special trade.

In Chapter XI. I have already described the special collecting vessels which are required in order to enable the brewer to comply with the excise regulations when, as in the above cases, he adds either syrup or wort to his finished beers. The greatest care must be taken to keep these vessels absolutely clean, and both the syrup and wort should in all cases be used as fresh as possible.

Of course those stouts which are intended for bottling and export must not be worted, and any blending must in their case be conducted in the most cautious manner, so that if any fermentative action is set up it may have subsided before the beer is bottled.

These stouts require also to have been vatted for a very considerable period extending generally over many months before they can be safely bottled for export.

I may here remark that the keeping properties of all varieties of black beer are greatly enhanced by the presence of those products derived from brown or black malt which have been produced in them by the high temperature to which they have been subjected.

Where brown malt has been used, we have the additional and very powerful effect of those matters analogous to creosote, derived from the combustion of the wood, and absorbed by the malt during the drying process.

The products of the simple action of a roasting temperature on the constituents of grain and malt are analogous to caramel, though, of course, only the amount of true caramel is produced that corresponds to the quantity of sugar existing in the grain. Caramel, as is well known, is incapable of undergoing fermentation, and the analogous matters derived from dextrine and starch possess the same characteristic; they also, to a certain extent, check or control the fermentation of those constituents derived from the pale malts.

It must, however, be clearly understood that it is only those coloured malts which are made from thoroughly sound grain which will enhance the keeping properties of the beers in which a proportion of them is used. I have already pointed out the disastrous results which arise from using black and other coloured malts made from unsound and damaged grain.

When black malt, made from sound barley malt, is employed it enhances the keeping qualities of the beers in which it is used, and the fact that black beers can be

safely worted and blended, in a way that would be ruinous in the case of ales, is partly due to the preservative effects of the black and other coloured malts.

There is one point connected with the racking of beer which I have already alluded to, I refer to the temperature of the beer when it is run into the trade casks, which is a matter of considerable importance.

If the beer is racked at a temperature of 60° or over, and the casks then transferred to some place at a much lower temperature, it is evident that not only will the slight fermentative action necessary to impart life to the beer be checked, but a partial vacuum will be produced in the cask, with the result of excessive flatness and the introduction of air through the shive or pores of the wood. To prevent these evils the safe rule is to rack the beer at a temperature some five or six degrees lower than that of the place where the beer is to be stored. With powerful attemperators, and a sufficient supply of cold water, beer can be generally sufficiently cooled before racking, and in all cases this end should be kept in view and carried out as far as the appliances will permit.

I have already alluded to the fining of ales before they are racked, but the more usual practice is to add the finings after the ales are racked into the trade casks. The artificial fining of ales is a matter of great importance now that new beers are preferred by the public, and I have already given receipts for making finings, both those called white finings, and those made with sour beer or brown finings. The former should alone be used in ales intended for the private trade, but publicans who fine their own beers shortly before they are going to draw them prefer the brown finings, which under such circumstances can be safely used, and have the

advantage of enabling the brewer to work off some of his old beer.

Some brewers add the white finings to their beers directly they are racked, and then shive them up tight at once, porousing them if necessary. This is a good plan wherever it can be adopted, but in many breweries it does not answer so well as adding the finings just before the beer is sent out. Every brewer must learn from experience which plan suits his beers best, and act accordingly.

As regards the quantity of finings necessary, when they are made with 7 lbs. of isinglass to the hogshead, from one to two pints per barrel ought to be sufficient. With very stubborn beers more may sometimes be required, and on the other hand less than one pint per barrel is sometimes enough; the general and safe rule is for the brewer to ascertain the smallest quantity of finings that will effect his object, and never to use more than is necessary.

In Dublin it is usual to add finings to the black beers. This is not the practice in other localities, except in the case of imperfect fermentations, when if the yeast will not separate from the beer, it of course becomes necessary to effect its removal artificially.

I have already spoken of the use of antiseptics in the early stages, when bisulphite of lime solution may be added to the mashing liquor and the mash, or the sulphites and bisulphites of the alkalies to the ground malt in the grist case. Antiseptics are also sometimes added to the beer during fermentation, when some brewers rouse in as much as a quart of bisulphite of lime solution to every ten barrels of beer, and others prefer one ounce of salicylic acid to every four barrels.

Antiseptics may also be added to the finished beer,

and it is at this stage that most pale ale brewers add bisulphite of lime solution, whether they have used preservatives in the earlier stages or not.

The proportion of bisulphite of lime, added at the time of racking varies from about one quarter to half a pint per barrel, and if necessary a further quantity may be added to stock ales when they are sent out.

Bisulphite of lime, added to the finished beer, is more effective as a preservative than when added in the earlier stages; but, on the other hand, it is also more apt to produce stench. In pale ales the flavour of Bisulphite is tolerated in many districts, but it is generally objected to in mild ales.

Monosulphite of lime may be added to the finished beers, and although not so powerful a preservative as the bisulphite, it is less liable to produce stench. Other monosulphites may also be used, such as those of soda and potash. Salicylic acid may be substituted for the sulphites, the proportion generally used being from one quarter of an ounce up to three quarters of an ounce per barrel. I have already, in Chapter XVII., gone so fully into the merits and demerits of this antiseptic that I need not say anything further here.

In preparing the casks for racking it is an excellent plan to give them a rinse with bisulphite of lime solution, and then to allow them to dry before filling them. By this means the internal surface of the cask is coated with a thin film of monosulphite of lime, which not only helps to destroy disease ferments in the wood, but also acts as a preservative to the beer. When casks have become acid, there is no better method of curing them than by treating them with bisulphite of lime, and storing them for some weeks with the heads out.

Beer may be stored either in the casks in which it is to be sent out, or in vats of larger or smaller size.

In former days vatting was almost universal, but since the great success of the Burton brewers has drawn attention to the superior advantages of their system for the production of the finer class of stock ales, vatting has gone more and more out of vogue, and is now almost confined to the storage of the stronger class of black beers and some special varieties of strong ale. For stout the vatting system seems alone capable of inducing those peculiar changes and the development of those ethers and flavours so much valued in the finest productions of the London and Dublin porter brewers.

Those fine old ales so much admired by our ancestors also best developed their properties in the vat, but the modern taste is content to dispense with the presence of those highly aromatic ethers formerly so much admired, as long as it can secure the absence of any large amount of the lactic acid which unfortunately so frequently accompanied these high flavours.

When storing ale in casks, it is necessary to provide against the excessive development of carbonic acid. This is usually effected by the use of the porous spile.

These spiles are made from the wood of the American black oak, which is full of tubular cells, running in the direction of the length of the grain. They are made about an inch long, and turned slightly conical. They are not pointed, but both ends are flat, and cut across the grain, thus allowing an egress for the carbonic acid as it is generated. As, however, they flatten the beer to some extent, I must impress upon brewers the advisability of replacing them by tight spiles a short time previous to the beer being sent out for consumption.

Many complaints of flat beer arise from this matter not being properly attended to, and also from the careless manner in which the spiles are inserted in the casks when set up in the consumer's cellar.

When beer has been long stored the tubes of the porous spiles become clogged with yeasty and extractive matters, so that after a certain time they cease to allow any carbonic acid to escape. This should be borne in mind when beers have to be stored for a very long period, and fresh porous spiles inserted when necessary.

The lower the temperature at which beer can be kept during storage, the less liability is there to the acid change; hence the great advantage of underground cellars, which can always be maintained at a moderate and equable temperature.

In many districts, however, such cellars cannot be constructed; and if the brewing process has been carried out to perfection they are by no means essential to the preservation of the beer.

In Burton the usual practise is to stack up the casks in open yards, covering them up by means of hurdles wattled with straw. As the warm weather comes on, further protection becomes necessary, and the casks are either placed in the now vacant malt houses, or the straw is frequently wetted during the day by sprinkling it with water.

Ales of sufficient strength, or pale ales in which a large proportion of hop has been used, can be stored in this rough manner with safety, but a great risk is run with the lighter class of ales unless they are stored in cool cellars.

It is therefore better, I think, to incur the risks of summer brewing, minimised as they now are by the

latest inventions and appliances, rather than to attempt to brew stock ales of a very light class. The only exception I would make is in those cases where cellars of the most perfect description can be secured.

By storing beer in good cellars, in which a uniform temperature of about 54° is maintained, almost all risk of the beer becoming acid is avoided, provided it is well brewed, and from good materials. There are, however, some inconveniences in this method of storage, for if the cellars are very cool, the beers stored in them are apt, when removed into a warmer atmosphere, to kick up, owing to their not having previously gone through that slow fermentation in cask, which is sure to take place sooner or later in all stock beers. On the other hand, if the cellars are maintained at a somewhat higher temperature, the beers are apt to chill, and become cloudy when removed in cold weather.

The fact is, that by coddling beers, while you certainly preserve them from disease, you are sure at the same time to render them tender, and susceptible to every change of temperature. Burton beers, in former days, were exposed by day to the heat, and by night to the frost, and, by this treatment, they became so hardy that they retained their condition and brilliancy under the most adverse circumstances.

During the course of this work I have repeatedly insisted on the paramount necessity of cleanliness in the brewery, and have explained both generally and particularly how this perfect cleanliness is to be maintained.

The brewer has to deal with substances which are excessively prone to decomposition, and yet he is doomed to failure unless he confines this decomposition within very narrow limits. It is, however, only the incorrigibly

careless who tolerate absolute filth in the visible and exposed portions of the brewing plant.

Most brewers are sufficiently persuaded of the absolute necessity for cleanliness to insist upon the mash tuns, coolers, fermenting tuns, and other vessels being thoroughly cleaned after and before each brewing, but too many are satisfied with this superficial cleanliness and examine but seldom into the state of the pipes, pumps and mains. Yet it is in these latter that the mischief so often commences.

Pipes, mains, and pumps may undoubtedly be long neglected with apparent impunity, but sooner or later the organisms which inhabit them are sure to pass from that comparatively harmless state, which appears to be their more usual condition, into a state of virulent activity.

When they have once assumed this virulently active state, it may, and often does, require months of the most unremitting care and attention before the brewer can again reduce these organisms to subjection, during which time the loss in money and credit is generally enormous.

As no brewer can say when this fatal change will occur, the only method by which safety can be secured is to take every opportunity of weakening and destroying the organisms, and preventing their collecting in the pipes, &c. In order that the brewer may be able to accomplish this all the pipes must be so arranged that both steam and boiling water can be flushed right through them, and a brush also passed without difficulty through every portion.

There is no real difficulty in arranging all pipes, mains, and pumps on this plan, and then the brewer can secure absolute safety as far as they are concerned, by washing

and steaming the whole after every brewing, and again steaming them just before he commences the following brewing.

With a well-arranged plant it is easy to maintain perfect cleanliness by the systematic use of steam, boiling water, and antiseptics, together with the frequent scrubbing and brushing of every accessible portion ; but when disease has once established itself in a brewery it requires weeks and even months of labour and constant vigilance to expel the enemy. Therefore, my last warning to my readers is, keep the enemy out of your breweries.

I do not know that I can conclude this treatise on Practical Brewing better than in the words slightly modified which I used at the end of the little work I published on the same subject some eight years ago, for now, as then, I hope I may truly say that I have endeavoured to give a faithful outline of the principles and process of brewing.

I do not presume to affirm that all that I have said on these points is absolutely unquestionable and irrefragable. Further experience in the brewery and the laboratory may, and probably will, modify some of the views I have endeavoured to demonstrate, or prove some of the deductions I have drawn from facts already established to be erroneous.

My intention has been to bring before the notice of practical brewers the scientific basis on which their practice is, or ought to be, founded, and to impress upon them the great importance of always keeping before their eyes the facts dependent upon invariable natural

causes, which scientific investigations have brought to light, and from due regard to which they can alone look for success in their operations, and so set forth clearly the nature of the obstacles with which they have daily to contend.

Of all these the most important are connected with the phenomena of fermentation, and the nature and condition of the water and other materials attainable for their purposes. On these points, therefore, I have dwelt at the greatest length. But there is another not so dependent on natural causes as on human infirmity: I mean the neglect of cleanliness, which in my experience I have found too commonly disregarded, even in some of the largest and most important breweries. Let me again, then, call the attention of my readers to the supreme importance of attention to this point, and if they have been impressed by the facts and observations that I have put before them, whether they accept and concur in *all* I have said or not, I shall not have written in vain.

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